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PARTS III & IV

# BIOLOGY--
# CHEMISTRY--
# PHYSICS

## A THREE-YEAR SEQUENCE

## STUDENTS' GUIDE

## PILOT SCHOOL EDITION

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# STUDENT'S GUIDE FOR

# BIOLOGY-
# CHEMISTRY-
# PHYSICS

## A THREE-YEAR SEQUENCE

## PILOT SCHOOL EDITION
## 1967

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# Part III:

# ENERGY AND WORK

- **Outline:** Energy and Work -

| SECTION | TOPIC | TIME | TEXT | EXPERIMENT |
|---|---|---|---|---|
| VII | Temperature, Calories and Keeping Track of Them | 6 days | | |
| VII.1 | | | IPS 11.1 | Demonstration: Calories |
| VII.2 | Heat and Temperature | | SG | |
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| VII.7 | | | SG | Heat Exchange |
| VII.8 | Observations and Laws | | SG | |
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| VIII.1 | | | SG | Demonstration: Brownian Motion |
| VIII.2 | The Brownian Motion of Smoke Particles | | SG | |
| VIII.3 | Explanation of Brownian Motion | | SG | |
| VIII.4 | Relevance of Brownian Motion to Thermal Motion | | SG | |
| IX. | Heat and Energy Conversions | 10 days | | |
| IX.1 | Types of Energy | | SG | |

| SECTION | TOPIC | TIME | TEXT | EXPERIMENT |
|---|---|---|---|---|
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| IX.4 | More Conversions | | SG | |
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| IX.12 | Chemical Changes and Energy Transfer | | SG | |
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## Chapter VII: Temperature, Calories and Keeping Track of Them

Hot fudge sundae? Apple pie a la mode? French fries? All these have plenty in common--plenty of calories. But what is meant by a calorie? Is the calorie you are thinking about the same as everyone else's?

You have used burners or heaters many times in your search for information about materials. How much heat were you using? Let's find out how to measure it.

### VII.1 - CALORIES

Now turn to and read IPS 11.1.

### VII.2 - HEAT AND TEMPERATURE

Does heat differ from temperature or are the two the same? When you measure the temperature of ice water or when you take your temperature are you actually measuring heat?

If you had a bathtub full of boiling water and took one cupful of water from it, would the water in the tub and the water in the cup have the same temperature? Would they contain equal quantities of heat? Which would take more ice cubes to bring it to 45° C.? Do you now see the difference between temperature and heat?

## VII.3 - CALORIES AND FOOD

You have learned that calories are a measure of heat and generally we measure heat intensity in terms of temperature. Then we can say calories are the measure of the amount of heat you can get from that hot fudge sundae, from a hamburger, from an apple or a pickle. Just how much energy (measured as calories of heat) is available from some common foods? We can find out using peanuts and filberts.

## VII.4 - Experiment: CALORIES IN FOOD

Using several successive pieces of nutmeat--peanuts, filberts, walnuts, etc.--try to find out how much heat is available from a given mass of nut. One way to start would be to stick a piece of nutmeat on a needle which in turn is embedded in a cork. Ignite the nutmeat which should be

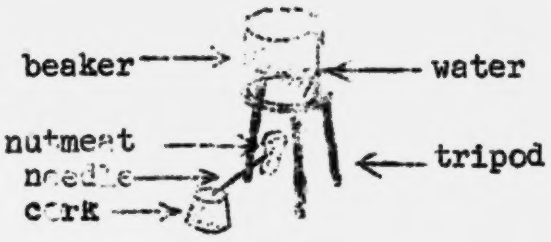


FIG. VII.1

in position under a small beaker (probably 100 ml) containing a measured amount of water. Measure the water temperature before and after burning the nut. If the nut stops burning, you may relight it once. If it goes out again, discard it and start over. Measure and record the available calories from at least three pieces of each kind.

Do your findings agree with those of your classmates? Did you get similar calorie counts each time? What factors are responsible for these inconsistent results? What might you do to increase the accuracy of your findings?

After devising an improved method or methods of measuring calories available from several samples of peanuts, walnuts or whatever kind of nut you used, tabulate the data for the whole class. How many calories are available in 1.0 g of walnuts? In 1.0 g of peanuts?

You need to know that the nutritional calorie is 1000 ($10^3$) times greater than that used by the scientist. When a diet

## VII.5 - Experiment: HEAT LOSS FROM THE HAND

Into four large beakers or bowls put enough water to cover your hand. With a thermometer in each, add ice to bring the water to 10° C. When the water has reached 10° C, remove the ice. Put your hand into the first bowl, holding it still for 5 minutes while your partner reads and records the temperature of the water at the end of each minute. The water in the beaker should be stirred gently with a rod during the entire period. At the end of the 5-minute period immediately plunge the same chilled hand into the second bowl of 10° C water and repeat the process for another 5 minutes. Have your warm-handed partner record the temperature readings. Now put your other, unchilled hand into the third bowl (also at 10° C), but as you hold it in the water move your fingers vigorously for the 5-minute period. Temperature in the fourth bowl should also be recorded for 5 minutes without holding your hand in the water. Why? With the accumulated data make a graph. Explain why the lines are not all the same. How could you calculate the number of calories put into each bowl? Can you trace the origin of the heat energy from the hand back to the sun?

Does this help you understand that the shipwreck victim tossed into the cold ocean soon dies because his body does not contain enough energy to heat the whole ocean?

### VII.6 - Experiment: HEAT LOSS AND SURFACE AREA

If you set a pan of hot water on the kitchen counter or the demonstration table, what happens to the heat? In some regions there are many lakes, large and small. The summer sun may warm them for several months. What happens to the heat held in such bodies of water as fall and winter come? Would two lakes of equal volume lose heat at the same rate if one were small and deep while the other was broad and flat?

Would a round balloon containing hot water (or a hot gas) lost heat as rapidly as a long, thin balloon containing the same volume of hot water? You can test this using watertight plastic bags. Into a plastic bag pour 400 ml of hot water (between 60° - 70° C). Insert a thermometer and suspend from a support stand or hold the bag quietly while your partner records the temperature readings at regular intervals for 15 minutes. Empty the water from the bag and repeat the process. This time, however, suspend the bag between two supports or hold it in such a way that the water is spread out over a much larger area of the bag. Be sure that the thermometer bulb is immersed. Would you get the same results by laying the bag of water on the counter top? Does this experiment tell you something about relative heat loss from a garter snake and a grass frog each weighing about 50 grams? When you climb into a cold bed, what is the most comfortable position to assume?

## VII.7 - Experiment: HEAT EXCHANGE

There are many more aspects of heat

to be considered. We have been trying to find out how much heat we can get out of something. We will now turn the problem around and find out how much heat we can put into something. For example, will water gain as much heat (as many calories) when its temperature is raised as it loses when the temperature is lowered?

You can answer this by mixing cool water with warm water, determining the heat lost by the warm water in cooling and calculating the heat gained by the cool water in warming. You will have to insulate the warm water from its surroundings as much as possible so it will not cool off by warming the surrounding air (like the sailor afloat in the sea). You can do this quite effectively by placing the warm water in a styrofoam cup in a beaker and pouring water at room temperature into it.

How much heat was gained by the cool water? How much heat was lost by the warm water? What was the change in temperature of the warm water? What do you conclude?

Why was the styrofoam cup covered? Why did you set it into a glass beaker?

## VII.8 - OBSERVATIONS AND LAWS

A physical law is a generalization based on experimentation. Calorimetry experiments led to a generalization called the conservation of heat which claimed the total amount of heat before any reaction equals the total amount of heat after the reaction. Defenders of this law found that all of the experiments which we have performed so far were consistent with this law. They said that heat may flow from one substance to another but that it is not lost. If a hot body is brought into contact with a cold body, heat will flow from the hot body to the cold body. If wood is burned, the heat in the wood is liberated.

Do you think the law of conservation of heat is true? How could you prove this law? How could you prove this law? How could you disprove this law?

From the observations you have made

so far, it is not unreasonable to consider the law of conservation of heat to be true. There are, though, other aspects of heat energy yet to be considered. When we look at these more closely, as we will in the next few chapters, we will find that the law is not true.

## Exercises for Home, Desk and Lab (HDL)

(1) A thousand grams of water are heated with an immersion heater. The temperature of the water rises from $10^\circ$ C to $25^\circ$ C. How many calories have gone into the water?

(2) A certain heater coil is known to supply 1000 cal/min. If this coil is placed in 500 g of water in an insulated container, (a) how many calories will the coil supply in 2 minutes, and (b) what will be the temperature rise in 2 minutes?

(3) In the experiment described in IPS II.1 what would have been the temperature rise if 4000 g of water

had been heated in the second tank while 2000 g of water in the first tank were heated 10° C?

(4) How many calories are needed to heat 1 g of water from its freezing point to its boiling point?

(5) Find the heat output of your home or apartment furnace or heater.

(6) Determine some of the various ways in which heat used in your community is measured.

(7) What problems would arise if you attempted to measure the calories (kilocalories) in milk? Cheese? Tomatoes?

(8) What are some low-energy foods? Some high-energy foods?

(9) In Part II, IPS Experiment 3.13, you plotted a graph of temperature against time for water being heated to the boiling point. From this graph would you predict that it takes less time to raise by 5° C the temperature of water at 90° C or water at room temperature?

(10) Could you measure heat loss from your exhaled breath? How?

(11)-

(a) If burning a 0.3 g piece of peanut raises the temperature of 10 ml of water 25° C, How many calories/gr are available in the nut?

(b) If burning a 0.7 g cube of dehydrated cheese raises 4 ml of $H_2O$ 8° C in temperature, how many calories are available per gram of cheese?

(12) You are shopping for a big party to be held 8 hours from now. The ice which you buy will be carried around in the trunk of your car, then stored on the patio until party time. Which should you buy--a large block of ice to be chipped up later, or an equal weight of ice cubes? Why?

(13) Would the situation be the same if you were shopping for a hunting trip, when the ice would be

stored for some days in a styrofoam cooler?

(14)-

(a) If 300 ml of 70° C water is mixed with 700 ml of 100° C water, what will be the temperature of the final mass?

(b) If 100 ml of 25°C water is mixed with 400 ml of water at 45° C, the final temperature of the total will be _______?

(c) What will be the final temperature if 125 ml of milk at 18° C is mixed with 250 ml of milk at 72° C?

(15) A bathtub contains $1.0 \times 10^5$ g of water at 25° C. How much water at 60° C must be added to provide a hot bath at 40° C?

(16)-

(a) In each of 2 beakers there is 100 ml of liquid at 20° C. To each you add 100 ml of 90° C water. The temperature in beaker X soon reaches 55° C.

The temperature in beaker Y soon reaches 75° C. How would you explain this?

(b) It takes more ice cubes to chill 1000 g of alcohol from 50° C to 20° C than it does to chill 1000 g of water through the same temperature range. Can you explain this?

(c) If it takes 10 peanuts to warm a given mass of water 10° C, it takes only a part of one peanut to warm an equal mass of lead 10° C. Why?

## Chapter VIII: Temperature and Chaos

We would like to know if a change in temperature affects the molecules of a gass or a liquid. Although we cannot see molecules, we shall find that we have a direct visual link with them.

### VIII.1 - BROWNIAN MOTION

If you look through a low-power microscope at some tobacco smoke particles suspended in air, you will see that the particles have a random, jerky motion. This effect is called Brownian motion in honor of Robert Brown who in 1827 discovered a similar motion in pollen grains suspended in water. A french physicist, Jean Perrin, later provided a qualitative explanation. He said that the random motion was due to the liquid (or gas) molecules striking the small suspended particles unevenly. In 1905 Albert Einstein published a complete mathematical treatment of Brownian motion. But before we say more, let's take time out to see for ourselves.

## VIII. 2 - Demonstration: THE BROWNIAN MOTION OF SMOKE PARTICLES

Smoke particles are so small that it is difficult or impossible to see what they look like with an ordinary microscope set-up. We may, however, see smoke particles by shining a strong light on them in such a way that only the light which scatters from the smoke enters our microscope. A 40-to 60-power microscope works well. Using this technique, smoke particles will appear as tiny stars against a dark background. Notice that the smaller particles exhibit more Brownian motion than the larger ones.

## VIII. 3 - EXPLANATION OF BROWNIAN MOTION

The effects you have just seen are due to the fact that air is composed of separate molecules. A smoke particle is so small that it can be knocked around by the even smaller faster air molecules which are striking it randomly on all sides. We cannot see the air molecules, but we can infer their existence from the zig-zag motion which they impart to the smoke particles. A very detailed treatment of our observations would relate the size of the air molecules and the size of the smoke particles to the amount of Brownian motion we observe. If the air molecules were larger, objects like BB's would exhibit Brownian motion, whereas if the air molecules were smaller, we would not see Brownian motion at all.

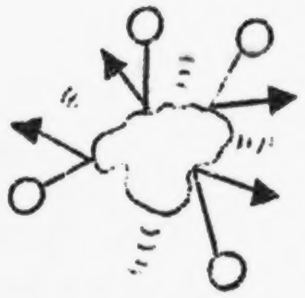


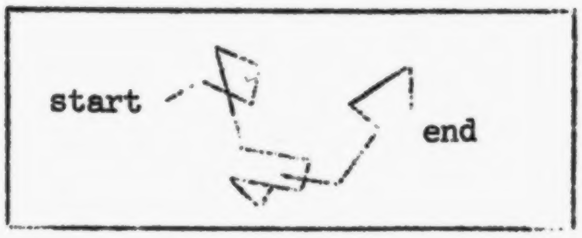
FIG. VIII.1

## VIII.4 - RELEVANCE OF BROWNIAN MOTION TO THERMAL MOTION

If it were practical to do so, we could increase the temperature and observe an increase in the Brownian motion of the smoke particles. From this observation we might infer that the smoke particles move faster when the air is warmer because the air molecules are moving faster. We might correctly guess that the temperature is related to the random motion of molecules -- that is, when the temperature of a substance is increased, the random motion of its molecules is likewise increased.

## VIII. 5 - DIFFUSION

Brownian motion also gives us a clue to understanding the process of diffusion. A smoke particle is several million times as heavy as an air molecule but, qualitatively speaking, it moves around like an air molecule. If you look through a microscope at some smoke particles in air, you will see that the smaller particles have more erratic motion than the larger particles. Not only are the air molecules several million times smaller than the smoke particles, but they also are moving much faster, on the average, than the smoke particles. Nevertheless, their two motions are similar. We call such motions, "random walks." You can imagine a random walk this way. Spin the arrow on a game spinner, then take a step in the direction in which the arrow points. Now spin the arrow again, taking a step in the new direction, etc. Such a process would not be very efficient for getting anywhere. Your path might look something like FIG. VIII.2.



A Random Walk
FIG. VIII.2

But after a long time you would probably be far from your starting place. Smoke particles move about in a similar way when air (convection) currents are eliminated. A particle would move in one direction with constant velocity until it is bumped by an air molecule which would cause it to move in another direction, etc. Each smoke particle would have a different path. After a time any given pair of particles would probably be farther apart. By this process called diffusion, an initially concentrated wisp of smoke gets spread out. By the same process, molecules from an open bottle of perfume will diffuse throughout the room. The perfume will diffuse more rapidly because the smaller perfume molecules "take larger steps" and take them more rapidly than the smoke particles do. However, if diffusion alone were occurring, it would take at least an hour for the perfume to cross the room. We know that the odor (molecules) crosses the room in minutes; this is the result of air currents. Now turn to and read IPS 10.1 and 10.2.

Exercises for Home, Desk and Lab (HDL).

(1) How would the photographs in IPS FIG. X.1 differ if

(a) the bromine evaporated more rapidly

(b) there were more air in the tube?

(2) When bromine vaporizes in an evacuated tube, the color seems to spread immediately throughout the tube. What does this tell you about the speed of bromine molecules?

(3) We learned in VIII.3 that the higher the temperature, the greater the Brownian motion because the higher temperature increases the speed or motion of the air molecules. Discuss the following:

(a) The molecules of a gas are colliding. If they are heated (go faster), do they collide with more violence?

(b) Is there any limit to how much heat you can add?

(c) Will anything happen to the molecules as they collide harder and harder?

(d) Is there any limit to how much heat can be withdrawn from an object?

(4) Suppose that smoke particles are placed in a chamber containing compressed air. How will the Brownian motion differ from that seen at normal air pressure? Suppose the smoke particles are placed in a partial vacuum. How will their motion appear? In complete vacuum?

# - Chapter IX: Heat and Energy Conversions

You have been reading about and working with heat energy concepts. We will now attempt to broaden our knowledge concerning other forms of energy.

## IX.1 - TYPES OF ENERGY

Energy is very difficult to define satisfactorily, so let's discuss instead what it can do; this will be a definition of sorts.

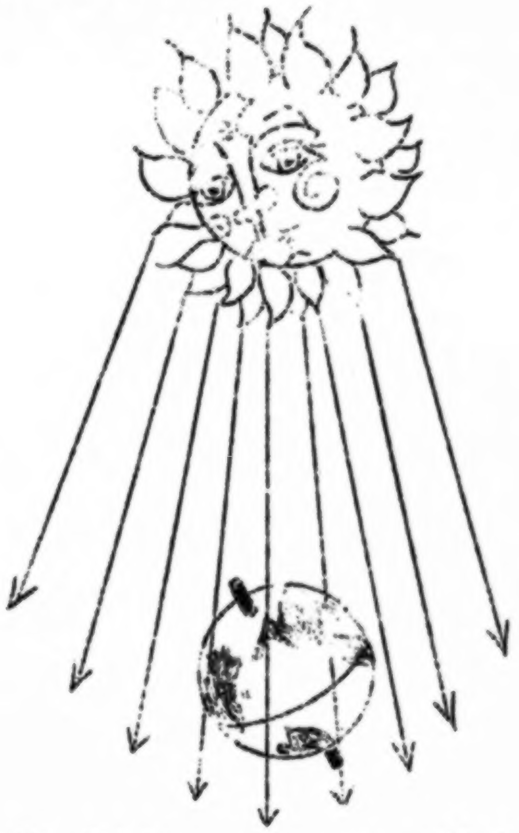


FIG. IX.1 . The sun radiates energy, some of which the earth recieves in the forms of light, heat, etc.

Heat can travel from the sun to our earth across the emptiness of outer space just as do light, ultraviolet radiation, x-rays, etc. These forms of energy are spoken of as radiant energy.

We previously saw that raising the temperature by an object gave its molecules greater movement. The heat energy was absorbed in the object and showed up as increased molecular motion. By getting its molecules all "hot and bothered" (more energetic), heat can not only boil water, but can also be used to move the rotor of a gas turbine. From the other point of view, heat can arise from an object in motion. Try rubbing your hands together as hard as you can. Did your palms get hot or not? Did you ever slide down a rope? Can your skin be burned in this manner? Maybe there is a kinship between heat and light, ultraviolet radiation and x-rays just as there is between heat and the kinetic energy of moving objects. (The root of the word "kinetic" comes from the Greek language. The "kine" of "kinetic" and the "cine" of "cinema"—motion picture—have a common root in the Greek word of "motion.") The scientific worker recognizes all these as different aspects of energy. There are others—chemical, nuclear and electrical energy—that we could also mention.

## IX.2 - ENERGY CONVERSIONS

Why are such apparently diverse items lumped under the single family name of energy? It is because they can be changed—converted from one into the other: heat to light; light to chemical energy; nuclear energy to heat; motion energy to heat. Often these conversions are reversible. For example, light can be changed back to heat under the right conditions.

### IX.3 - Demonstration: CONVERSION OF ELECTRICITY

Let's consider an example of these energy-to-energy conversions. The apparatus involved is shown in FIG. IX.2. Begin with the rheostat turned so that no current is flowing. The ammeter (an instrument which measures the flow of electricity) reads zero. Next turn the rheostat so that a bit of current flows, but do not light the lamp. Can your fingers detect heat coming from the bulb? If so, then you are witnessing this conversion:

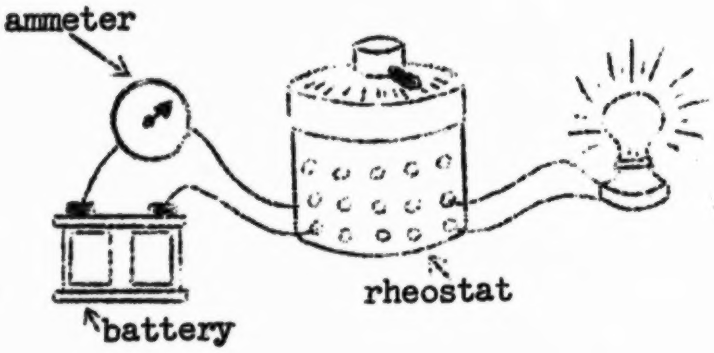


FIG. IX.2 The Conversion

Electricity ⟶ Heat

where the arrow "⟶" means yields, produces or converts into.

Now turn the rheostat slowly to higher and higher settings. Light is now being produced in addition to heat.

Electrical Energy ⟶ Light and Heat

What color was first to appear? As the current increased, did the color remain the same?

We have seen above that light bulbs convert electricity to heat and light. It is interesting to note that most of the electrical energy given to a light bulb is turned into heat. Light bulbs are better "heaters" than "lighters." They are often used to keep chicken houses and incubators warm and are sometimes placed near water pipes, etc., that are in danger of freezing in very cold weather.

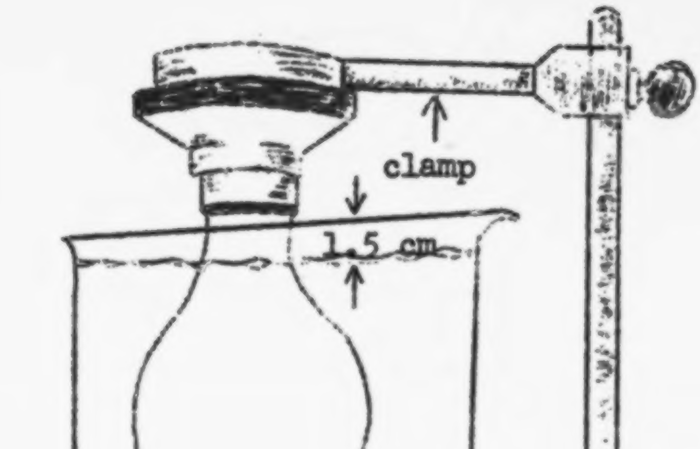

clamp
1.5 cm
ringstand

FIG. IX.3

We buy bulbs by wattage—50 watt, 75 watt, 100 watt, etc. This wattage is a measure of the rate of their energy output when plugged into a household circuit.

In a given time does a 100 watt bulb produce twice as much energy as a 50 watt bulb? What would you expect the ratio to be between a 100 watt bulb and a 75 watt bulb? What would you expect the ratio to be between a 150 watt bulb and a 75 watt bulb? Consider other combinations.

The data table below is blank and should be left blank. But the class under the teacher's direction may gather a similar set of data. Use a 1000 ml beaker with 800 ml of water if regular household bulbs are used. We suggest a heating period of 4 minutes.

| Bulb | $T_1$ (°C) | $T_2$ (°C) | Calories Produced in Water |
|---|---|---|---|
| 60 w | | | |
| 75 w | | | |
| 100 w | | | |
| 150 w | | | |

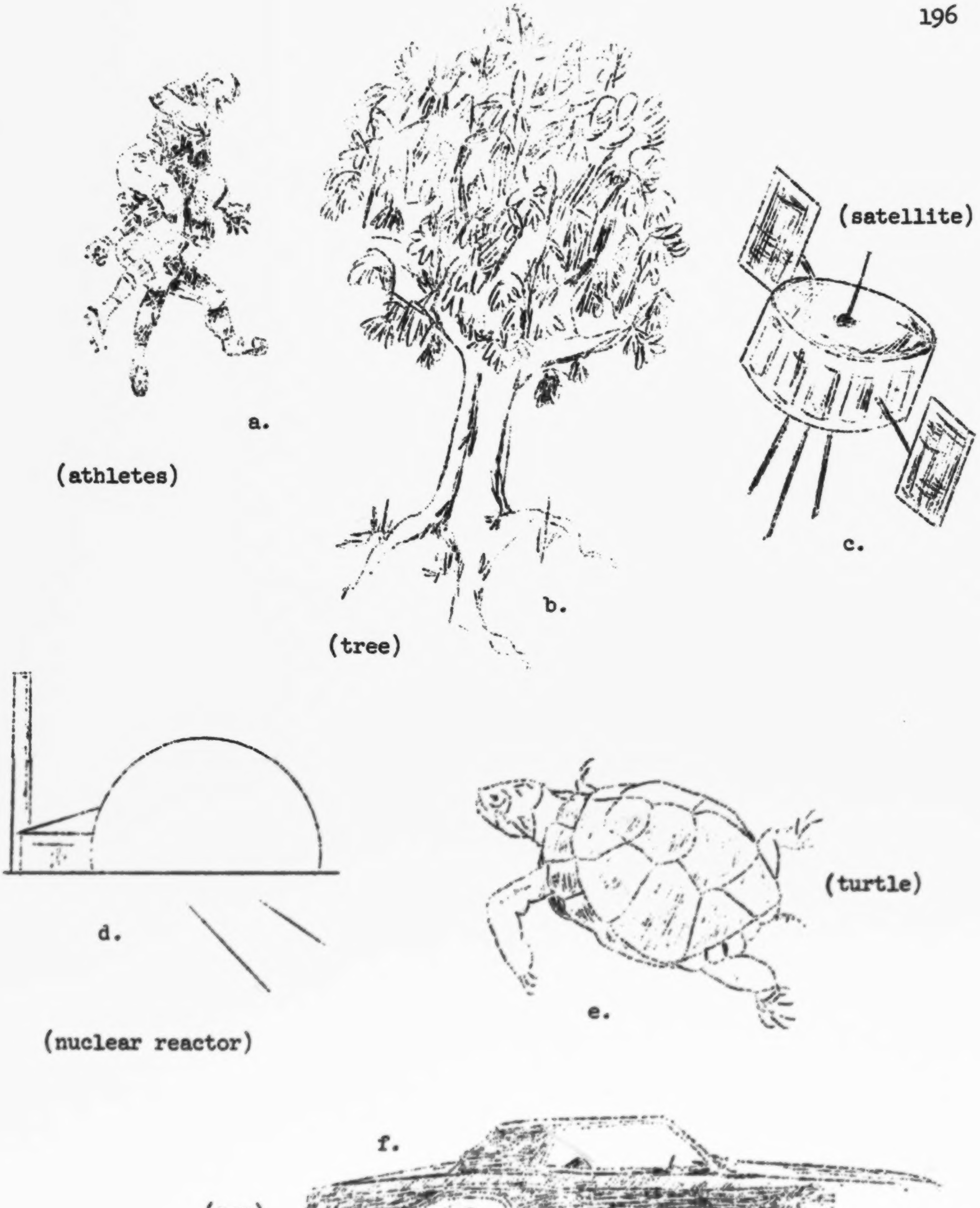

a.
(athletes)
b.
(tree)
(satellite)
c.
d.
(nuclear reactor)
(turtle)
e.
f.
(car)

FIG. IX.4

## IX.4 - MORE ON CONVERSIONS

If electricity can be turned into light, then a natural question follows: can light be turned into electricity? In recent years we have heard much about solar cells and batteries. Our space vehicles make extensive use of them. FIG. IX.5 indicates what a single cell might be like, while FIG. IX.4f on the previous page indicates how a space vehicle may have large panels containing a great many cells on each panel. Each single cell yields only a minute current; large areas covered with these cells are necessary to get useful amounts of energy. We do not need to discuss the inner processes of the solar cell at this time in order to appreciate that it involves the following conversion:

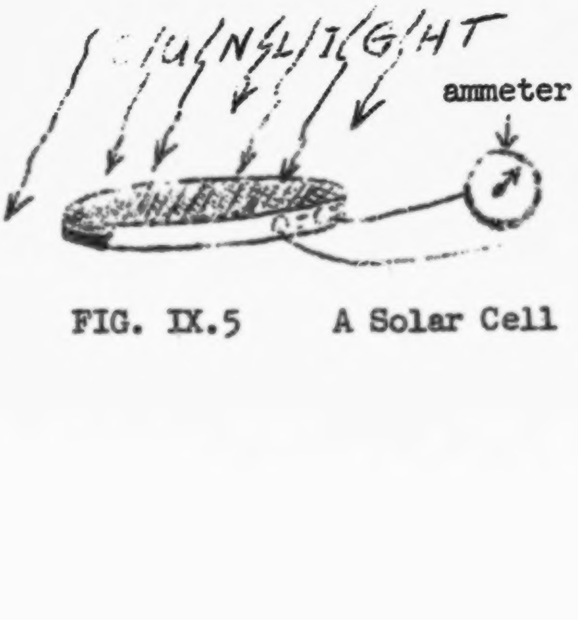


FIG. IX.5 A Solar Cell

## Light ——>Electricity

It is important to think of the solar cell as an energy converter. Several kinds of these light-to-electricity converters have been developed and find extensive use in photography and other activities where measurement of light is important.

We have shown that the electricity-to-light conversion can be reversed. What about electricity-to-heat conversion? Can it also be reversed?

### IX.5 - Experiment: HEAT TO ELECTRICITY

Take a strand of copper and a strand of iron wire and bare the ends if they are insulated. Arrange them as shown in FIG. IX.6c. An end of the copper wire is twisted together with an end of the iron wire and the other two ends are connected to a galvanometer. What happens when you heat the junction of the two wires? You notice that electricity flows in the circuit. Will it continue as long as you keep heating? What happens if you heat it slightly as compared to heating it intensely? Immerse the junction in ice. What results?

It is interesting to note that near the beginning of this century this type of converter was used experimentally to power telegraph systems. In recent years we have seen a number of pictures and references in the press about radio for people living in primitive situations such as Siberia or the Australian Bush. The radios are powered by a device placed in the heat from a kerosene lantern. In future years the sun's rays may be used to produce electricity for your home in a similar manner.

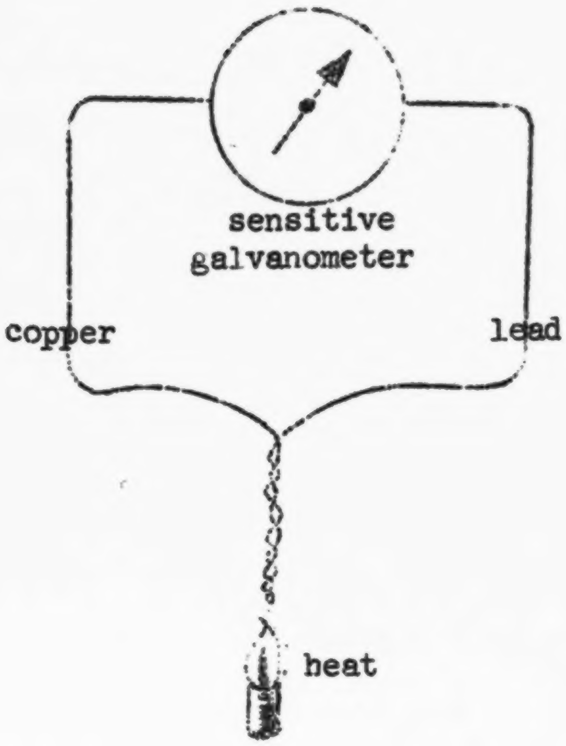


FIG. IX.6c

## IX.6 - CELL RESPIRATION

We get energy from food and when we use muscle power, we are making use of that energy. Consider the example of rubbing the hands together to produce heat. What energy conversions are involved? It is something like this:

chemical energy stored in food ---> energy stored in our muscles ---> heat energy at the palms

Remember when you burned the peanut and measured the heat produced? Is the heat produced by rubbing your palms together generated through the same process?

When you eat a bag of peanuts or a cheese sandwich, do you feel a warm "glow" all over? Of course not. Do you suppose that all those calories (how many would there be in a 90 g bag of peanuts?) are used to heat you? Not likely. How does your body use these calories? Remember that this refers to a measure of heat. Packaged calories come disguised as hot-dogs, pizza, carrot sticks and in many other forms. Some of these packages contain a lot of potential heat (calories). Why then don't you just go up in smoke?

The clue to this is in the way the food is broken down or utilized within you—or any other living organism, for that matter. The energy tied up in that package is released bit by bit and piece by peice in a process called cellular respiration. This respiration, which refers to activities at the level of atoms and molecules, is not to be confused with the respiration which we refer to when we talk about breathing. Cell respiration can be defined as the step-by-step release of energy from food.

Where does the energy go? Some of it does, in fact, serve as a source of heat for you. You expect to maintain your body temperature at 37° C (98.6° F) all the time. For other organisms "normal" temperature might be higher or lower than this. In song birds it is 45° C; in hamsters it is 36° C; in dogs it is 38.6° C. In each case we expect the healthy individual to maintain this temperature whether he finds himself in the arctic wastes or on a tropical island. This is just one example of the many ways in which some living systems maintain a constant condition by using energy. Do all living systems maintain a constant temperature? What determines a lizard's or fish's temperature?

Much of the energy available from cellular respiration is given out in forms other than heat as indicated in FIG. IX.7.

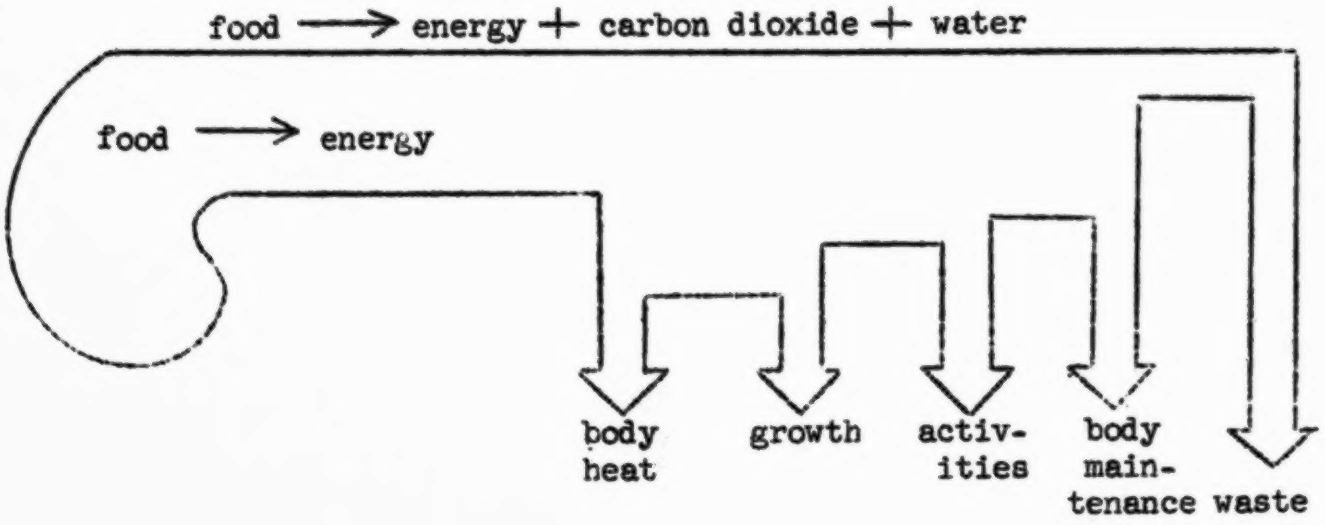

food → energy + carbon dioxide + water
food → energy
body heat
growth
activities
body maintenance
waste

FIG. IX.7 Respiration releases energy for use in organisms.

These will be used for many purposes with which you are familiar including things like energy for activities. Which would require a greater energy source—dancing or doing housework? Gardening or golfing? Is energy required when you are at complete rest?

It is interesting to note the similarity between energy use in living organisms and in gas engines. Comparing FIG. IX.7 and FIG. IX.8, observe that the two systems start with similar products—food or fuel and oxygen—and end with similar products—energy, carbon dioxide and water.

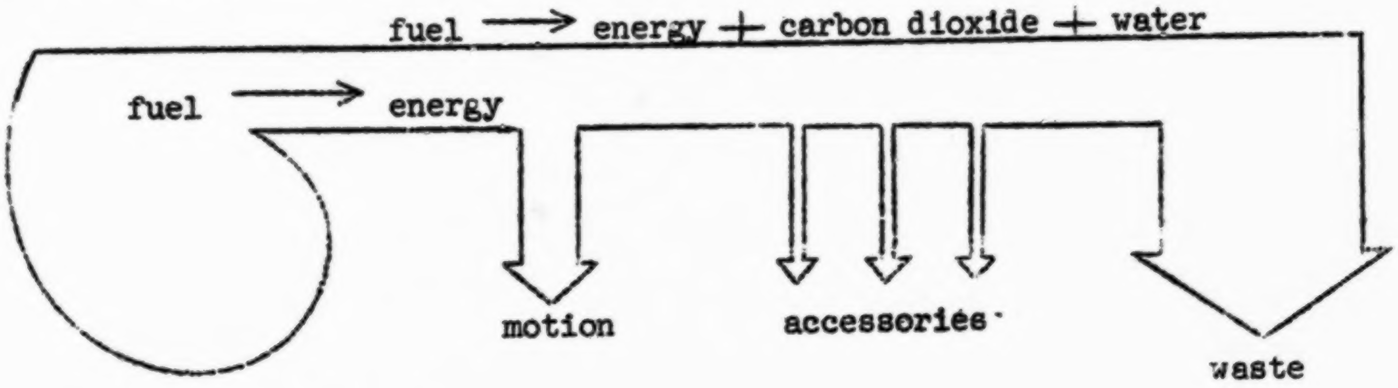

fuel ⟶ energy + carbon dioxide + water
fuel ⟶ energy
motion
accessories
waste

FIG. IX.8 Energy Distribution from Gasoline-Powered Car

## IX.7 - HEAT CONDUCTION

There is another characteristic of heat energy conversion that needs to be considered. Say that a friend of yours is leaning against the outside of a metal shed. You are inside with a blowtorch. You put the flame near the wall. There is a pause. Suddenly you hear your friend cry out. What has happened? Does the series of energy conversions below represent what took place?

energy stored in the fuel → radiant heat from the flame →
higher random motion of the molecules of the wall → higher random motion of your friend' molecules

It is this increase in agitation of the molecules to which the pain sensitive nerves in our bodies react.

Let's examine part of this conversion in greater detail. The wall is composed of molecules which have a certain amount of random motion at room temperature. When the heat of the flame reaches the surface, it is converted into motion energy of the surface molecules. Therefore, they vibrate more energetically and interact with their neighbors. The simplest way to think of it is that the energized molecules "bump" neighboring molecules transferring this extra energy of vibration. By this molecule-to-molecule transfer of energy, the far surface of the metal also becomes hot. This movement of heat energy from molecule to molecule is called conduction. When the surface became hot on the side where your friend was leaning, conduction was also the method which transferred the energy into him.

### IX.8 - Experiment: RADIANT ENERGY AND ABSORBING SURFACES

What determines how much heat is absorbed when radiant heat energy hits an object? Is all of it absorbed? If only a portion is absorbed, what determines the amount that is absorbed?

Place a bulb 100 watt or bigger in a socket on a table. At equal distances from it place several identical flasks, air-filled, stoppered and with a thermometer in each. One flask is covered with soot, one covered with aluminum foil and one left as it is. Take initial temperature readings in each. Turn on the bulb and take temperature readings at 1 minute intervals. If 1 minute intervals are not saitisfactory, change to a different time interval. Plot a temperature vs. time curve for all three flasks on one graph. After you have plotted enough data to determine the heating curve shapes, turn off the heat source and continue plotting.

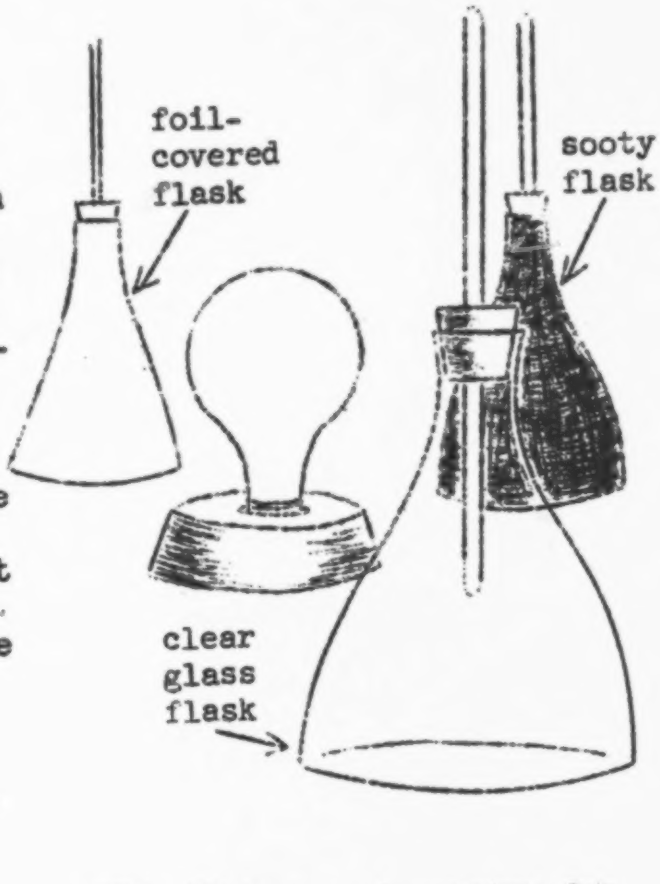


FIG. IX.9a - Apparatus for Radiation Absorption Experiment

What curves are you plotting now? Which surface absorbs the most heat? Which the least? Why do you think this is so? Why do the curves reach a plateau? Suppose the bulb had a higher heat output. How would this have affected the curves? Was the best heat absorber the best radiator of heat? How do you know the bulb radiates equally in all directions? How could you find out?

### IX.9 - Demonstration: CONVERSION OF MECHANICAL TO ELECTRICAL ENERGY

One more demonstration of an energy conversion will help clarify the concept better. Many high schools have small hand-cranked generators. Turning the crank takes muscular energy, that rotates the crank and inner parts of the generator.

As these parts spin, their mechanical energy (mechanical energy simply refers to the energy of motion of the moving parts) is converted into electricity. Holding your fingers against the wire leads will prove that this conversion is taking place. If you are hesitant, you may prefer to have a light bulb of low wattage attached in order to demonstrate that electrical energy is in the wires.

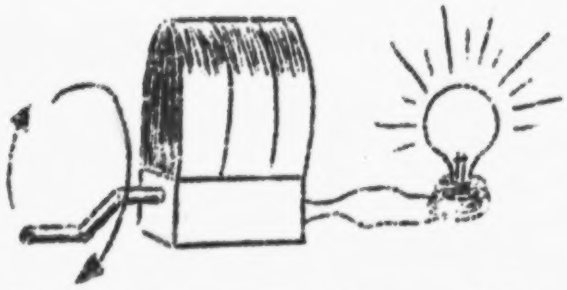


FIG. IX.10 - The Conversion of Mechanical Energy to Electrical

$$\begin{array}{c}\text{electrical}\\ \text{energy}\end{array} \longrightarrow \begin{array}{l}\text{mechanical energy}\\ \text{of rotating parts}\end{array}$$

The explanation of "why" and "how" the above conversion occurs will have to wait for the latter part of our three-year course.

We have seen that a generator is a device that turns the rotational energy into electricity. What do you call the device that turns electricity into rotational motion?

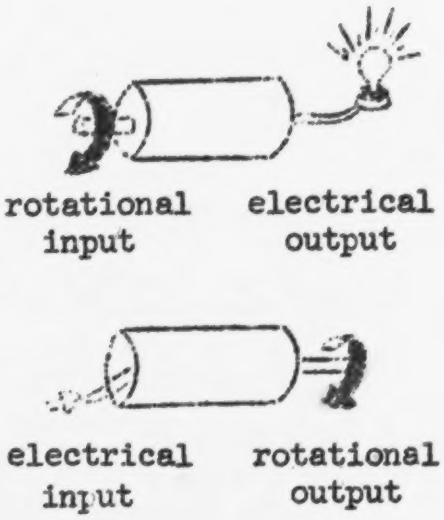


FIG. IX.11

IX.10 - CHEMICAL ENERGY

Everyone is familiar with fire but not all people know that fire is a chemical interaction involving fuel and oxygen. In this kind of interaction "energy-rich" molecules are converted to new kinds of molecules having lower energy content. The energy is released as heat and light; we say that chemical energy is converted to heat and light energy.

You might explore some chemical changes involving heat by doing the following experiment.

### IX.11 - Experiment: EXOTHERMIC AND ENDOTHERMIC REACTIONS

Place about 10 grams of granular ammonium chloride into 50 milliliters of water at room temperature. Record the temperature before you add the ammonium chloride and then record the temperature every 30 seconds until the temperature levels off. What did you discover? This is an example of an endothermic chemical change. Look up the definition of the term endothermic.

Using extreme caution, place about 10 grams of sodium hydroxide (lye) into 100 ml of water in a 250 ml beaker.

(DO NOT COME IN CONTACT WITH THE SODIUM HYDROXIDE OR ITS SOLUTION.) As in the first part of the experiment, record the initial temperature and successive changes in temperature. Find the definition of the term exothermic. Does it apply to this interaction? Would you describe the burning of a fuel as an exothermic or an endothermic interaction?

Make a graph of the temperature changes versus time for each of the above interactions. Place both on the same graph. How do the curves compare?

## IX.12 - CHEMICAL CHANGES AND ENERGY TRANSFER

In chemical changes which take place spontaneously the new molecules usually have less chemical energy than the parent molecules. Whenever newly formed molecules have more chemical energy than was present in the parent molecules, the chemical interaction requires a continuous input of energy in the form of heat, light or electricity. The electrolysis of water produces hydrogen and oxygen molecules which are richer in energy than the water molecules they come from. This process of electrolysis requires a continuous input of electrical energy.

Sugar is a compound rich in chemical energy. It is produced by green plants from the less "energy-rich" molecules carbon dioxide and water. This is a complex biochemical change called photosynthesis which requires a continuous input of energy. It is interesting to note that the production of sugar is a process which suggests a reversal of the burning of fuels. Is photosynthesis similar to the operation of the solar cell? Would you consider the green plant to be a type of energy converter? Would you agree that vegetation stores solar energy?

Electrolysis of water involves the change of electrical energy to chemical energy. The reverse process is also possible: chemical energy can be converted to electrical energy. We can show this by doing the following experiment.

IX.13 - Experiment: A "PENNY" BATTERY

Sandwich about three layers of paper toweling moistened with salt water between an iron washer and a penny (FIG. IX.12). Touch the two wires from the galvanometer to opposite sides of the "sandwich." Observe the needle on the galvanometer. Try reversing the wire connections.

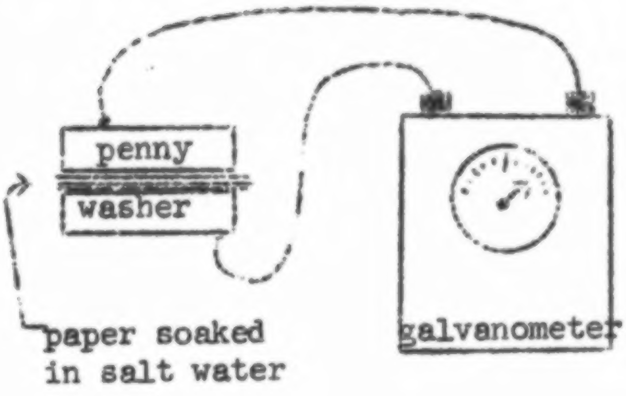


FIG. IX.12

You have just made an energy converter called an electrolytic cell. This is similar to the commercial "dry cell." What materials are used in a flashlight cell?

Place a strip of zinc or aluminum metal and a strip of copper into some citrus fruit (FIG. IX.13). Touch the wires from the galvanometer to the strips of metal and observe the galvanometer. If you can obtain a thick piece of pencil lead (carbon), insert it into the citrus fruit in place of the copper strip. What do you observe? What happens if both strips are of the same kind of metal?

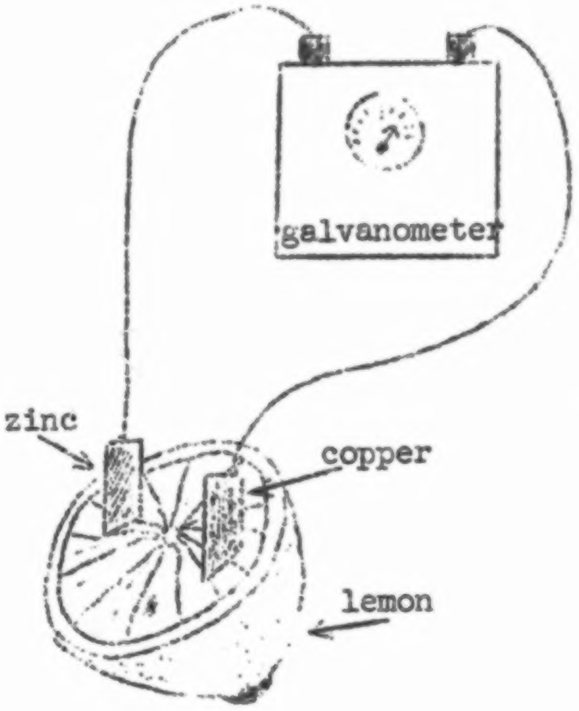


FIG. IX.13

What would happen if you were to replace the citrus fruit with a piece of raw meat? What might happen if you touch a metal spoon to one of your tooth fillings?

You might be interested in the experiments done by the Italian physiologist and physicist, Luigi Galvani. Use your library.

### IX.14 - Demonstration: CHARGING AND DISCHARGING

In the preceding experiment you observed that electrical energy may result from chemical interactions. This conversion of chemical to electrical energy is very useful. Every time you use a flashlight or other battery operated device, you are making use of just such energy conversions. Batteries are really energy converters.

The following demonstration will serve to illustrate the process involved in charging and discharging the lead-acid battery.

Place two clean lead strips (approximately 3 x 20 x 100 mm) into about 150 ml of dilute sulfuric acid (about 0.1 molar). Connect the two lead plates to the terminals of two #6 dry cells as shown in FIG. IX.14 and observe the changes at both lead plates. After the process has continued for several minutes, try lighting a flashlight bulb with the charged cell by removing the wires from the dry cells and connecting them to the flashlight bulb.

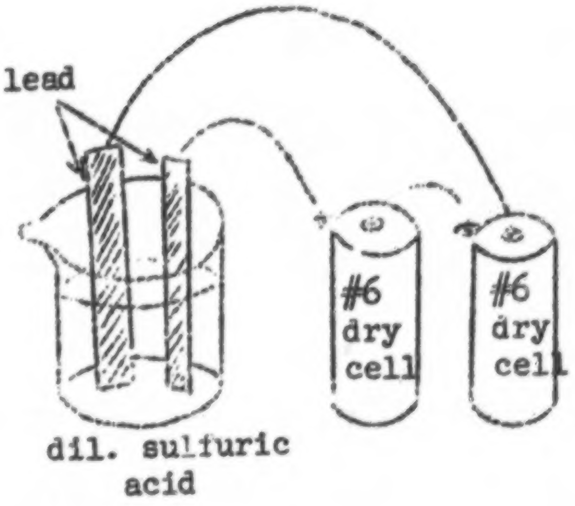


FIG. IX.14

The automobile battery is an interesting energy converter. During the charging process, electrical energy produced by the generator causes an increase in chemical energy of the battery. On discharge, the battery loses chemical energy as it furnishes electricity. This may be illustrated as follows:

$$\text{Chemical Energy} \underset{\text{charging}}{\overset{\text{discharge}}{\rightleftarrows}} \text{Electrical Energy}$$

It is important to point out that the energy is stored primarily as chemical energy rather than as an accumulation of electrical charges. You will learn more about such chemical and electrical conversions later in this course.

## IX.15 - ELECTRICITY: WE ARE ALL CHARGED UP

Life itself—at least in the higher organisms—depends in part on electric impulses that arise from chemical energy. Our own neural and muscular systems operate in this manner.

In some animals such as the electric ray (Torpedo nobiliana) and the electric "eel" of the Amazon, considerable energy may be produced. The North Atlantic electric ray can deliver as much as 50 amperes at 50 to 60 volts. We might point out that most fuses in your home would be blown out by a current of more than 20 amperes. An African catfish is able to produce a 350-volt shock, while the Amazon electric "eel" can generate enough electricity to light several household light bulbs. It can, in fact, deliver a jolting 500 volts. As you can well imagine, the current generated by such voltages may kill a man.

The organ within an electric fish which produces electricity may account for about 80% of the fish's bulk. It is made up of columns of tiny structures called electroplaques. There may be more than fifty such columns each consisting of about ten thousand electroplaques. Nervous stimulation of the electroplaques causes chemical energy to be converted to electricity.

Strange as it may seem, plants, too, are capable of producing electricity. The growing root of a bean shoot has been found to act as an electric generator producing very feeble electric currents. Even the microorganisms get into the act. Scientists have recently been experimenting with fuel cells in which bacteria produced the electricity. All of these organisms are energy converters in which biochemical changes produce electric energy.

## IX.16 - LIGHT AND CHEMICAL ENERGY

The candle, kerosene lamp and gas lantern are also converters of chemical energy. These converters are primarily used as sources of light although most of the chemical energy is converted to heat. To be highly efficient as a light producer, the chemical energy should be converted to a "cold light." A chemical interaction in which the bulk of released energy is converted to light and not heat is called chemiluminescence.

On a warm summer night youngsters in the Midwest often amuse themselves by catching "lightening bugs" or fireflies. These fascinating insects are found flying leisurely above the lawns, producing greenish flashes of light. The light produced in the insects' abdomen is a "cold light" resulting from chemical interactions. The biologist calls this process bioluminescence. There are many more examples of bioluminescence in a variety of other organisms. Again we see an example of energy conversion:

$$\text{Chemical Energy} \underset{\text{photosynthesis}}{\overset{\text{bioluminescence}}{\rightleftarrows}} \text{Light Energy}$$

There are many unanswered questions concerning life processes. Since all life depends upon energy conversions, some of the answers to these questions will come from a better understanding of energy conversions in biological systems.

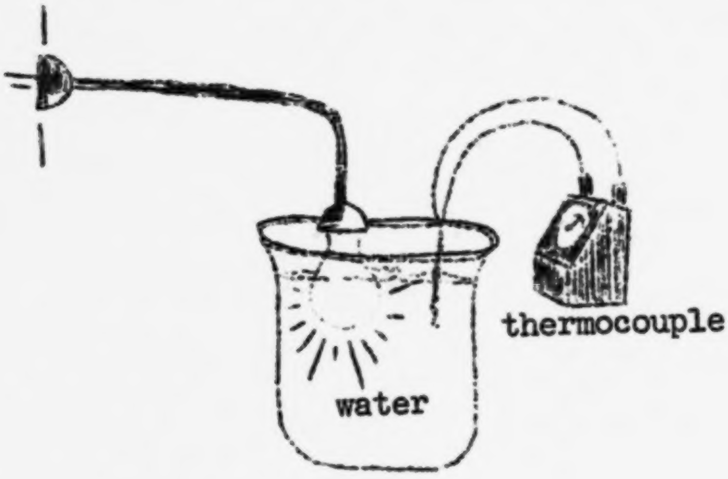
## Exercises for Home, Desk and Lab (HDL)

(1)-

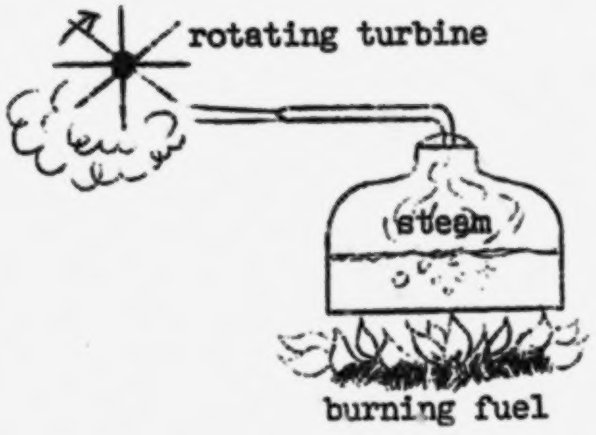
(a) What heat or temperature changes are noticed in a roomful of people when doors are closed? Explain.

(b) Arrange a series of household tasks or activities in order of decreasing energy requirements.

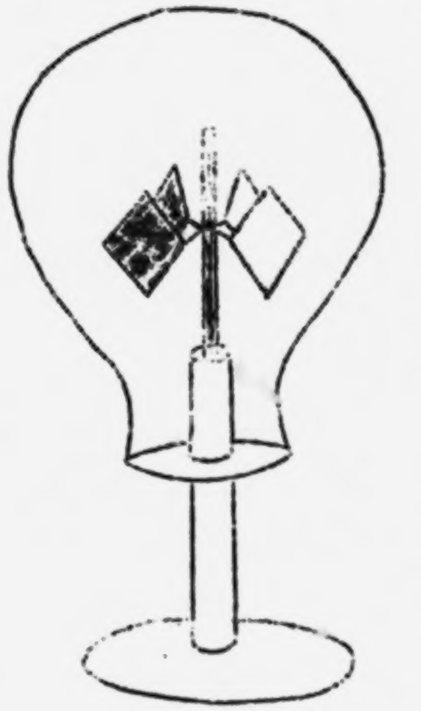
(2) Broaden your knowledge of ultraviolet, infrared, x-ray, gamma, cosmic and visible radiation, and other related topics by reading further in encyclopedias, paper backs, etc. Use your library.



(3) Use the "$\rightarrow$" to indicate the energy conversions occurring in this set-up.


rotating turbine
steam
burning fuel

(4) Use the "⟶" to indicate the energy conversions occurring in this apparatus.



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(5) You have seen the "eye catching" device pictured above. It is often seen in shop windows—put there to get you to

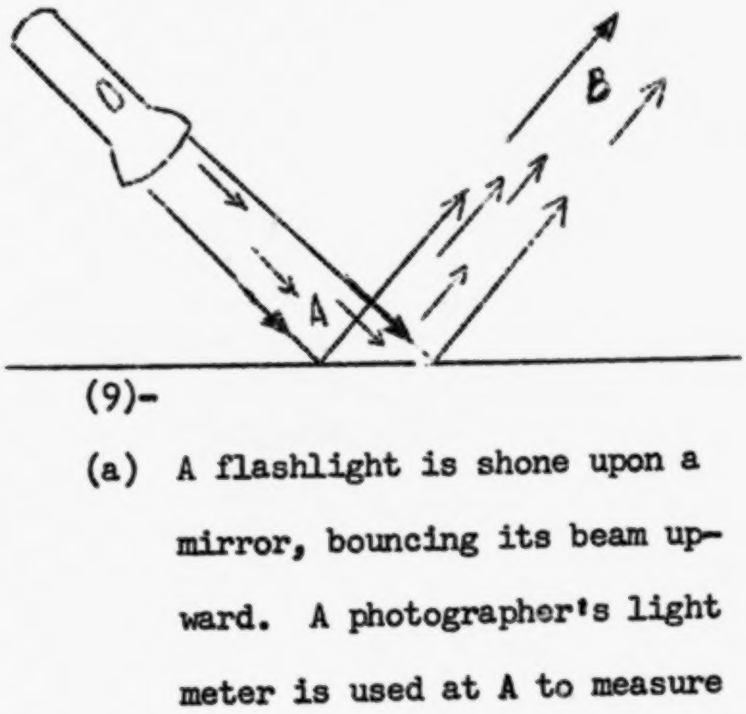
stop. It spins with no apparent source of energy. What energy conversion is involved? Speculate on what makes it operate?

(6) The sun is the ultimate source of the energy man uses during his life. Trace the energy of rotation (kinetic energy) of the Bonneville Dam generators back to the sun. Use the "⟶". Do likewise with the energy in the sugar of a candy bar.

(7) In the demonstration of Sec. IX.8, does 100% of the electrical energy go into raising the water temperature? Can you think of at least four energy "leaks"? How would you go about "plugging up" this leak?

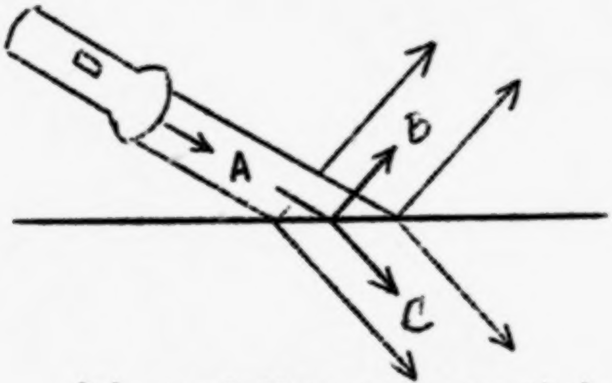
(8) Suppose that in the demonstration in Sec. IX.8 we had found a 4-minute trial with a 100 watt bulb would raise the temperature of 800 ml of water $4.0^{\circ}$ C. How many calories were produced? Use this result to fill in the table of predictions.

| Bulb Size (watts) | Water Volume (me) | Time (min) | Heat Produced (calories) | Temp Change (°C) |
|---|---|---|---|---|
| 200 | 800 | 4 | | |
| 100 | 1600 | 4 | | |
| 200 | 800 | 12 | | |
| 100 | 400 | 8 | | |
| 1000 | 400 | ½ | | |
| 100 | 800 | | | 1.0°C |



(9)-

(a) A flashlight is shone upon a mirror, bouncing its beam upward. A photographer's light meter is used at A to measure the light approaching the mirror, and at B to measure the amount of light leaving the mirror. Experimentally, B is smaller than A. Speculate on what happened to the missing light.



(b) A similar arrangement is made with the light shining on a smooth water surface. If 100 units of light pass A, experimental results show something like 40 units arriving at B and 40 units arriving at C. Some of the light has reflected but some has entered the water. Speculate on what may have happened to the missing 20 units of light.

(10) It has been discovered that radioactive materials yield heat.

$$\text{nuclear energy} \longrightarrow \text{heat}$$

Would the reverse process be possible?

$$\text{nuclear energy} \longleftarrow \text{heat}$$

Try to answer this question by reading about radioactivity in outside references.

(11) The fuel cell is an energy converter which is being used in some specialized industries. What substances are consumed by the fuel cell in the generation of electricity? What are the waste products from the cell? How will these products affect air pollution as more cells come into general use? (Use your library.)

(12) The bunsen burner is an energy converter. What substances are consumed by the burner? What are the main products

of combustion? Show the energy conversions in a scheme similar to the one in section 9.4.

(13) "Chrome" plating of automobile parts involves an energy conversion. Show the energy conversions involved in this process.

(14) Gas engines will run on a mixture of hydrogen and oxygen as well as on gasoline and air. This same gas engine can be used to drive a generator which will produce electricity. The electricity can decompose water into hydrogen and oxygen. Show the energy conversions involved in this operation. Would this system continue to operate on its hydrogen and oxygen output if it were fed into the gas engine?

(15) What is a thermopile?

# Chapter X: The Work-Energy Conversion

## X.1 - WORK

Many words have a general meaning for the man in the street and a different, more specific meaning to the scientist. One of these words is "work." This word is often used in everyday phrases or words such as "give it the works," "fireworks" or "a work of art." This useful word can have many common meanings. When used as a scientific term, however, it has only one very precise meaning.

Work is applying a force and causing an object to move. It has two aspects--a force that is applied and a movement which results. A lot of energy is used when a man tries to move a mule that does not want to move. But, according to our definition, no work is being done. Why? The answer should be obvious: neither the man nor the mule is moving. Something like brainwork, then, is, scientifically speaking, not work. Home-work is not work either except in that you may be moving a pencil in the process.

The scientist calculates work from the simple relationship

work = force x distance.

What units would be involved in the use of this formula? You have already used metric units of length. Suppose we measure the distance in meters. The unit of force which is used with metric units is the newton. It will take about 1 newton to overcome gravity and keep $\frac{1}{4}$ lb of material from falling. To hold up a 1-lb bag of oranges (or any other material) will require a force of approximately 4 newtons (FIG. X.2). You can see that a newton is a small amount of force. Nevertheless, whenever you hold up something, you are using some force to overcome the force of gravity.

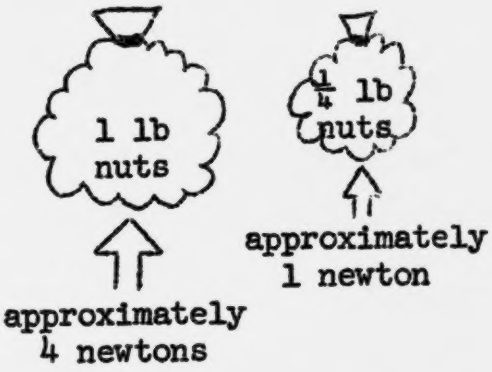


FIG. X.1 - The Unit of Force Called the Newton

What about the unit of work? If a 1-newton force is applied and moves an object 1 meter in the direction of the force, we say that a newton-meter of work has been accomplished. The newton-meter is given a special name--the joule.

Suppose that it takes a 3-newton force to lift an object 2 meters. The amount of work done is

work = force x distance

work = 3 newtons x 2 meters

work = 6 newton-meters (joules).

Now suppose the object is lifted 20 meters instead of only 2 meters. This requires 60 joules of work. It is then placed on a shelf at the 20-meter level. What would happen if it fell from the shelf? It might dent the earth, crack the floor or shatter. All of these processes require work. We could arrange the object to fall on a nail and drive it into a plank. Let's determine how much work the falling object could do on the nail. Sixty joules of work were used in raising the object. When it sits on the shelf, it has the potential capacity to do 60 joules of work.

We speak of this capcity to do work as potential energy. The object on the shelf has 60 joules of potential energy --something it did not have before it was lifted. It is important to understand that even though it has not changed physically, it now has this ability to do some work because of its position relative to the earth. Therefore, it can do 60 joules of work on the nail, floor or whatever it hits in falling.

Let's follow this change step by step. The object is raised. Work is done on it and its potential energy (PE) is increased.

W ⟶ PE

When the object is dropped, its PE is used to do work.

PE ⟶ W

The word "potential" is an appropriate choice here. If you say that a person is "potentially" a good artist, you mean that "stored" inside of him are the necessary talents to become a fine artist. Similarly, potential energy is "stored" energy.

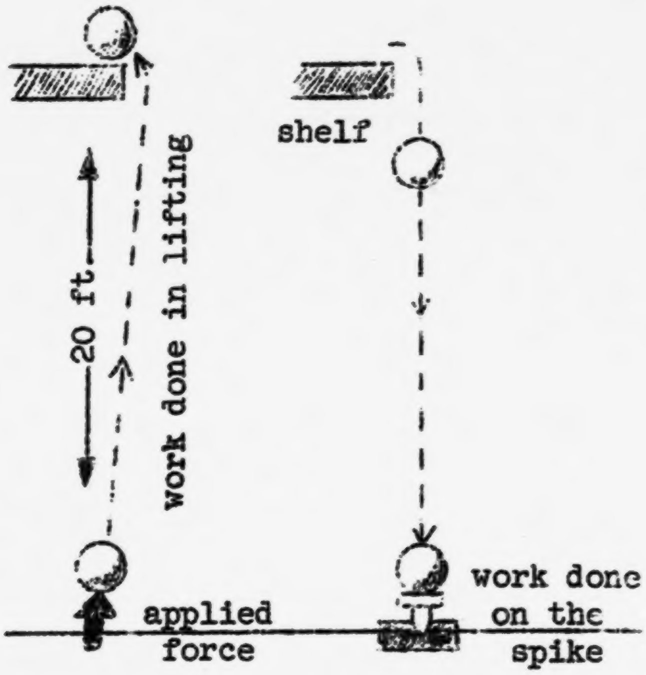


FIG. X.2 - Stored energy in raised object is released as it falls, thus enabling it to do work.

We have been speaking of gravitational potential energy. This is not the only kind of stored energy. Do you remember the sundaes, pizzas, etc. from a previous discussion? Before you eat them, they contain potential energy. Another example of potential energy can be seen in the compressed spring (FIG. X.3). We have to do work to compress the spring. When held in the compressed position, does the spring not contain the stored ability to do work like the object on the shelf? Place a block against the spring and release. It applies a force through a distance--some work--and pushes the block away. As the spring uncoils, the block is hurled towards a wall. Just before it hits, it has considerable speed or motion. Suppose a nail is projecting from the wall. The nail would of course be driven in. To drive the nail requires that work be done; the moving object was able to do this work.

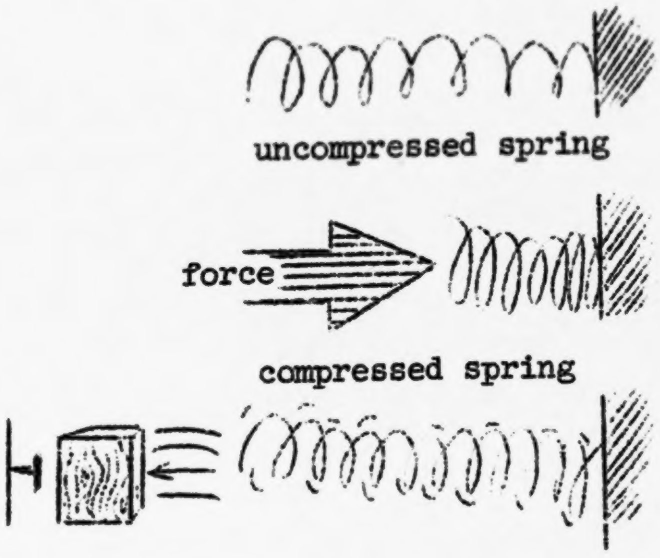


FIG. X.3 - Spring Doing Work against a Block

## X.2 - KINETIC ENERGY

Any object in motion has the ability to do work upon another object by applying its force for some distance. The energy associated with moving objects is called kinetic energy. We can gain some insight into kinetic energy by considering a few well-directed questions. Upon what does the energy of a moving object depend? Which would have more kinetic energy--a Volkswagen at 50 mph or a Greyhound bus at 50 mph? Which would have more kinetic energy--a Volkswagen at 50 mph or a Volkswagen at 80 mph? Now the first question again. Upon what factors does kinetic energy depend?

Kinetic energy under the right conditions can be transferred from object to object. Consider the billiard balls in FIG. X.4.

KE of X $\longrightarrow$ KE of Y

Not only can part of the energy be transferred but under the right conditions virtually all the energy can be trans-

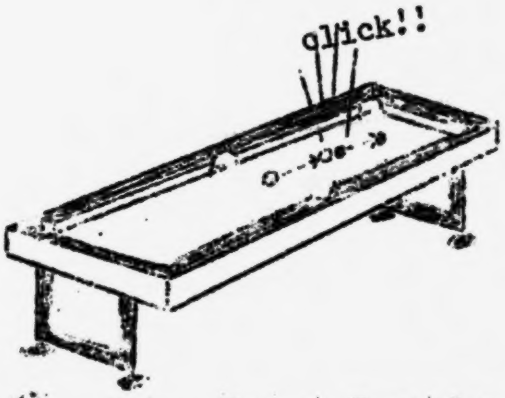


FIG. X.4 - Energy Transfer in Billiard Balls

ferred. Many pool players can put a backspin on the cue ball such that on collision the cue ball stops while the target ball hit speeds away. Even here, however, there is doubt that all of the KE of X went to Y. Did you notice that "crack"? Could part of the KE of X have been lost in sound energy?

## X.3 - POTENTIAL ENERGY TO KINETIC ENERGY

Now go back and reconsider the fall of the object upon a nail. We said that the potential energy of the object 20 meters above the nail was what enabled it to do work upon the nail. BUT--a split second before it hit it did not have the height and therefore lacked potential energy. It had something else --motion or kinetic energy. When it had fallen half way down, it had lost half its potential energy but gained some kinetic. Three-quarters of the way to the nail it had lost three-quarters of its potential energy but had gained more kinetic. At the instant of impact all the potential had been converted to kinetic energy.

PE ⟶ KE ⟶ Work

This will summarize the entire lifting and dropping process:

work done in lifting object ⟶ PE of object on shelf
⟶ KE gained as object falls ⟶ work done upon nail

When considering the nature of the work-energy relationship, remember that work is done when and only when *energy* is *transferred*. Recall the block forced against the spring. The compressed spring has stored potential energy. On being released, the spring does work on the block. Suddenly the spring has lost energy. Now the block has kinetic energy. KE has been transferred during the work process to the block. In each case that we observed, energy was transferred when work was done. Can you think of any exceptions to this?

## X.4 - Experiment: THE PENDULUM

Hang a pendulum bob by a string from a solid support (FIG. X.5a). Pull it back and release it. Note how high it goes at the opposite end of its swing and on its return to the origin point. Did the bob have as much PE when it returned to point A as when it started from point A? After successive swings? What other kind of energy besides potential energy was involved? How long until all the energy you gave it by pulling it back to the release point, has been lost? What has become of it?

Now arrange a rigid rod to interrupt the swing (FIG. X.5b). Now how high does the bob swing? What about the height upon its return to A? What conclusion can you come to concerning these energy exchanges? Try putting the interrupting bar at different levels. Did you also try beginning the swing at point B?

Can you express the energy conversions involved here by using the "→" notation?

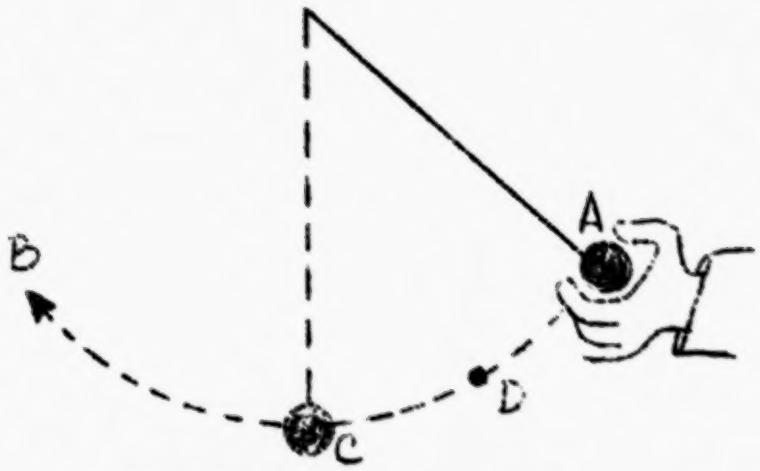


FIG. X.5a - The Pendulum

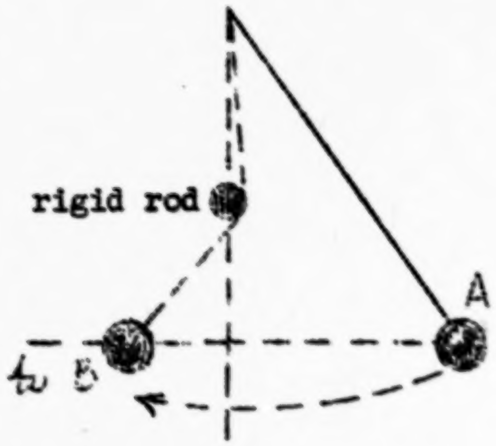


FIG. X.5b - An Interrupted Pendulum

## X.5 - CYCLIC CONVERSIONS

The word cyclic refers to something that repeats like the seasonal changes. On a wheel any spoke or point on the rim comes around periodically or in cycles. Sunspots appear on the sun's surface in an eleven-year cycle--first many spots, then few, then many again.

## X.6 - Demonstration: THE INERTIAL BALANCE

FIG. X.6 shows an apparatus called an inertial balance. Pull it to one side and watch it swing back and forth. You can see that it is like two flexible hacksaw blades. Try adding material to is platform. C clamps can be hooked on easily. What happens to its vibration when the extra material is hooked on? Do you see a similarity to the pendulum in the previous experiment?

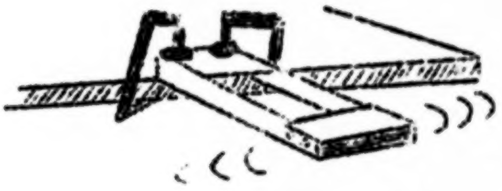


FIG. X.6 - A Horizontal Pendulum

Similarity of motion is easily seen, but maybe the differences are more striking.

The regular or gravitational pendulum could be explained by this series:

work done in lifting bob to initial point → PE (gravitational) → KE →
→ PE (grav.) → KE → PE (grav.) → etc.

The apparatus we are watching is not lifted. When pushed sideways, the PE results from doing work to bend the spring-like metal blades.

work done in initial bending of blades → PE (spring) → KE →
→ PE (spring) → KE → PE (spring) → etc.

This change can repeat itself over and over in cycles for a long time. If no energy was lost, could such a vibration go on forever? Or would it? Do repeated or cyclic energy conversions occur only in non-living materials or do they also take place in living organisms?

## X.7 - Experiment: THE CASE OF THE FALLING STUFF

In the chapter on calorimetry (Chapter VII), the question was asked, "Is heat conserved?" The following experiment will help you find an answer.

Obtain a mailing tube about 1 meter long and 3-5 cm in diameter (the exact dimensions are not critical). Use large stoppers to close the ends. Make a small hole in the mailing tube about 1 inch from one end so that a theremometer can be inserted from the side. Put a cup or two of lead shot into this apparatus. With the lead at one end, take the temperature of the lead (it should be very close to room temperature).

Determine this temperature, remove the thermometer and cover the hole with your finger or other suitable instrument. Rotate the tube so that the shot is raised to the upper end and falls the length of the tube. Repeat this action rapidly until the lead has fallen fifty times the tube length. Record the temperature of the lead. Repeat. What is the temperature after one hundred falls? One-hundred-fifty falls? Two hundred? Two-hundred-fifty? Three hundred? Plot a graph of temperature versus number of falls. What caused the temperature change? Is heat conserved? Do the results of this experiment change your ideas about the conservation of heat?

What would have been the results if lead had not been the falling material? Suppose it had been some other solid like sugar or even a liquid such as water? Let's suggest an hypothesis: any falling material will yield heat on impact no matter what the material is. We test the hypothesis with an experiment. You can use sugar as another material. Data referred to was obtained using water.

FIG. X.10 shows the apparatus for this test. A glass tube was used. It was first wrapped with several layers of paper to reduce the heat losses.

Only one-half degree of rise for all that falling! The tiny rise was not due to hands since the tube was held by clamps to avoid heat transfer. Before you conclude that the one-half degree is an error, remember that many significant things have been overlooked for centuries simply because they were small. Also, no matter how insignificant the change in temperature, it represents an exception to the conservation of heat. Heat came into being where it did not exist before. Therefore, the conservation of heat cannot be true because a physical law cannot have any exceptions. Even if we had not seen other examples of heat arising from other forms of energy, the small amount of heat produced from the kinetic

| Falls | Water Temp. ($^oC$) |
|---|---|
| 0 | 23.4 |
|  | 0.1 |
| 50 | 23.5 |
| 100 | 23.6 |
| 150 | 23.7 |
| 200 | 23.8 |
| 250 | 23.9 |
| 300 | 23.9 |

energy of our falling stuff would have been sufficient to discount the law of conservation of heat.

We have seen many examples of energy forms changing but no examples of energy showing up where none existed before. Nor have we seen any evidence of energy going out of existence. Could it be that energy is conserved?

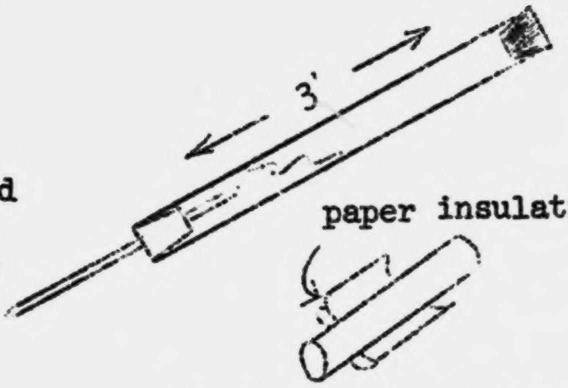


FIG. X.10 - The "Falling Water" Apparatus

A strong positive or negative argument concerning this suggested law requires more information than we have at this time. So we must withhold final judgment on this issue.

Exercises for Home, Desk and Lab (HDL)

(1) A 50-newton force is used to lift an object 10 meters above its ~~m~~ original position.

(a) How many joules of work are done?

(b) Suppose that the same object falls back to the original position. How much work can it do at this surface?

(c) Suppose that instead of falling, the object skids down a slope and in doing this, one-half of its energy is converted to heat. How much energy will it still have (how much work can it do) on reaching the original level?

(2) Two hundred joules of energy are done in raising an object from level A to a higher level B. The object is allowed to fall one-half the distance back to A. How much work can it do upon arrival at the midpoint, assuming one-third of the energy was lost in frictional waste during the fall?

(3) Two automobiles approach at 40 mph and collide head-on. Before the collision each contained kinetic energy. They do not bounce apart, but remain a stationary wreck. There is no appreciable skidding. What happened to the kinetic energy?

(4) Prepare three drinking glasses in the following manner:

- A - no treatment
- B - wrap in newspaper
- C - wrap in wrinkled newspaper and set in larger glass or mug

Into each pour 100 ml of hot water. Measure the temperature of each at regular intervals for 20 minutes, then plot the cooling curves. Is 20 minutes sufficient for tracing the change?

- (a) What does this teach you about insulation in homes?
- (b) Why are wool blankets effective as bedding?
- (c) Why can birds perch outdoors at 0° C without freezing to death?
- (d) Are feathers or fur better insulation?
- (e) Would lids on the glasses make any difference?
- (f) Could this experiment have started with ice-cold water?

Repeat experiment with a thermos bottle.

(5) In section IX.1 we referred to the difficulty of defining energy in a satisfactory manner. Traditionally textbooks have used the statement, "Energy is the ability or capacity to do work." Write a few paragraphs (your teacher may prefer an oral discussion) on whether you think this definition is justified or not.

(6) Why does a nail become hot when it is hammered vigorously?

# - Chapter XI: The Second Law and Trends in Nature -

The law of conservation of energy places no serious restriction on man since there is plenty of energy around. Unfortunately there is a second law which severely limits our using this abundance of energy.

## XI.1 - AN IMPOSSIBLE MACHINE

The water in the ocean contains fantastic amounts of energy in the form of random moleculer motion. If one were to extract a sufficient amount of this energy, the water would turn to ice. Why is it that no one uses this extracted energy for doing work? It would not be inconsistent with the law of conservation of energy to extract heat (thermal) energy from the ocean and, say, run a sawmill aboard a ship. Why would a ship be unable to get power to cruise the oceans by gulping in ocean water at the bow, extracting thermal energy and dumping cakes of frozen seawater out the stern?

## XI.2 - THE SECOND LAW

Although such a ship would be consistent with the law of conservation of energy, scientists have a second law which says, in essence, that it is impossible to have such a machine. It states that all machines which convert thermal energy to work (heat engines) must have two reservoirs at different temperatures. The engine can take heat from the reservoir at the higher temperature (source) and convert only some of the heat to work; the rest of the heat will be expelled into the low temperature reservoir (sink). FIG. XI.1 schematically illustrates the second law.

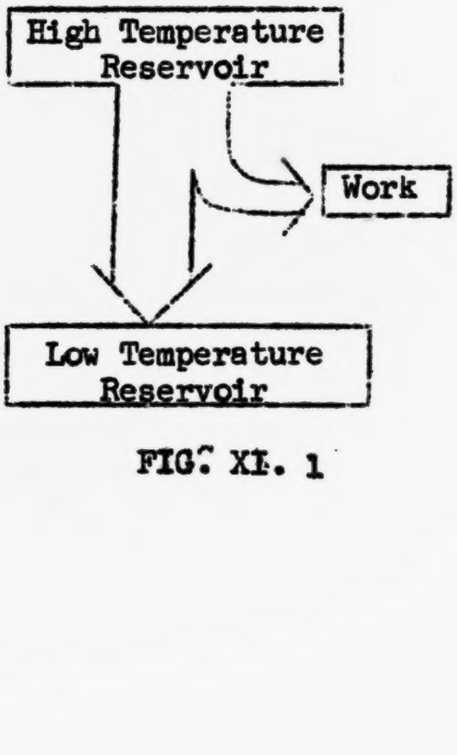


FIG. XI. 1

## XI.3 - A POSSIBLE MACHINE

One could operate a machine which utilized the temperature difference between the warm surface waters and the cold deeper waters of the tropical ocean. Such a machine, designed and built by Georges Claude, is described in the interesting paperback book Engineer's Dreams by Willey Ley (Viking-Explorer Books, the Viking Press, New York). However, Claude had a severe limitation since the second law relates the maximum efficiency of the heat engine to the temperature difference between source and sink. When this difference is small (as it is between a surface temperature of 27° C and 5° C for deeper, tropical ocean waters), the law states that the efficiency will be low. In practice, his design fell so short of the maximum possible efficiency that the net efficiency of his machine was near zero. Discouraged, he sank all his machinery in the ocean; he was an idealist. If, his machinery had worked only a little better, he would really have harnessed an unusual heat source.

## XI.4 - TRENDS

Nature has a trend that this second law implies. It is possible to have a ship use stored energy to warm the ocean. But the thermal energy of the ocean is unavailable unless there could be a reservoir at a still lower temperature. Therefore, the reverse process — extracting energy from the water to be stored on a ship, — is not possible. Energy can change from the available (fuel on ship) to the unavailable state (warm ocean), but not *vice versa*.

Biological organisms furnish another illustration of the trend in nature for energy to become less available. An interesting example is the system involving an earthworm, a robin and decomposing leaves. The leaves contain available energy. The robin is not equipped to harvest this energy. The earthworm can. It stores a small amount of the energy in its body, but most of the energy it takes in is eliminated in a degraded form (heat, castings). Thus, the worm's net effect on the leaves is to make their energy less available. A small portion of the energy originally in the leaves (that portion converted to earthworm tissue) does, however, remain available. It is this energy that the robin harvests.

Exercises for Home, Desk and Lab (HDL)

(1) What does the word "efficiency" mean to you?

(2) If the power input of an electrical motor was 600 watts and the power output was 400 watts, what would you say the efficiency of the motor was? You do not need to know what a "watt" is in order to answer this question.

(3) The water underneath the arctic ice has a temperature near 0° C whereas the air above the ice may have a temperature near -40° C. Could one use thermal energy in the sea water of the arctic for running a heat engine?

(4) A mathematical formula for the maximum possible efficiency of a heat engine is

$$m = \frac{t_1 - t_2}{t_1 + 273^\circ}$$

Here $t_1$ is the temperature of the source in °C; $t_2$ is the temperature of the sink in °C, and m is the maximum possible efficiency. What was the maximum possible efficiency of Georges Claude's heat engine? In practice, the efficiency of his machine was less than m.

(5) What is the maximum possible efficiency of the heat engine described in problem (3)? What would m be (using the formula in problem 4) if $t_2$ were $-273^\circ$ C? We are not making any statements as to whether or not it is possible to attain that temperature.

(6) Why is so much made about the "fuel cell"? (It has not been discussed but many students may have learned about the fuel cell in the newspapers or on TV.)

# Part IV:

# ECOLOGY

## - Outline: Ecology -

| SECTION | TOPIC | TIME | TEXT | EXPERIMENT |
|---|---|---|---|---|
| XII | Energy Transfer within Communities | 5 days | | |
| XII.1 | Community Energy Exchange | | SG | |
| XII.1a | | | SG | Energy Exchange in a Human Community |
| XII.2 | Food Chains and Food Webs: Transfer of Energy and Matter in a Community | | (Blue)<br>30-6 to 30-8 | |
| XII.2a | | | SG | Plant and Animal Relationships |
| XII.3 | The Nature of Photosynthesis | | (Blue)<br>9-5 to 9-7 | |
| XII.3a | | | SG | Release of Oxygen during Photosynthesis |
| XII.3b | | | SG | The Role of Pigments and Light in Photosynthesis |
| XII.4 | Structure of Multicellular Plants in Relation to Photosynthesis | | (Blue)<br>19-4 to 19-8 | |
| XII.4a | | | SG | Chloroplasts in Elodea Plants |
| XIII | The Variety of Living Things | 8 days | | |
| XIII.1 | Classifying Living Things | | (Blue)<br>2-1 to 2-8;<br>pp. 14-19,<br>34-43 | |

| SECTION | TOPIC | TIME | TEXT | EXPERIMENT |
|---|---|---|---|---|
| XIII.1a | | | SG | Classifying Living Things |
| XIII.2 | The Kinds of Living Things--Animals | | (Blue)<br>(Appendix)<br>pp. 677-682 | |
| XIII.2a | | | (Green)<br>Ex. 4.1 | Structural Characteristics in Classification of Animals |
| XIII.3 | The Kinds of Living Things--Plants | | (Blue)<br>(Appendix)<br>pp. 675-677 | |
| XIII.3a | | | (Green)<br>Ex. 5.1 | Diversity in the Plant Kingdom |
| XIII.3b | | | (Green)<br>Ex. 5.2 | Diversity among Angiosperms |
| XIII.4 | The Kinds of Living Things--Protists | | (Blue)<br>(Appendix)<br>pp. 673-675 | |
| XIII.4a | | | SG | Living Things in Pond Water |
| XIII.4b | | | (Green)<br>Ex. 7.7 | The Abundance of Airborne Microorganisms in Various School Environments |
| XIII.4c | | | SG | Effect of Temperature on Growth of Microorganisms |
| XIV | Descent with Modification | 23 days | | |
| XIV.1 | The Means of Evolution: Two Conflicting Views | | | |
| XIV.1.1 | Views on Evolution before Darwin's Time | | (Blue)<br>3-1 to 3-2 | |

| SECTION | TOPIC | TIME | TEXT | EXPERIMENT |
|---|---|---|---|---|
| XIV.1.2 | Darwin's Theory of the Means of Evolution | | (Blue) 3-3 to 3-8 | |
| XIV.1.3 | Adaptations and Selection | | (Blue) 3-9 to 3-11 | |
| XIV.1.3a | | | (Green) Ex. 10.1 | Paleontological Comparison |
| XIV.1.3b | | | (Blue) Invest. 9 | Investigation: Natural Selection Observed |
| XIV.1.4 | The Origin of Living Things | | (Blue) 4-1 to 4-10 | |
| XIV.1.4a | | | (Green) Ex. 6.2 | Demonstration: Experiments on Spontaneous Generation |
| XIV.2 | Patterns of Heredity | | | |
| XIV.2.1 | Heredity and Environment | | (Blue) 15-1 to 15-4 | |
| XIV.2.1a | | | (Green) Ex. 16.1 | Heredity and Environment |
| XIV.2.2 | The Work of Mendel | | (Blue) 15-5 to 15-7 | |
| XIV.2.2a | | | SG | Soybean and Corn Genetics: Mendel's Approach |
| XIV.2.3 | Probability and Genetics | | (Blue) 15-8 to 15-12 | |
| XIV.2.3a | | | (Green) Ex. 16.2 | Probability |
| XIV.2.4 | Hereditary Patterns | | (Blue) 15-13 to 15-17 | |
| XIV.2.4a | | | (Green) Ex. 19.2 | Human Blood Groups |

| SECTION | TOPIC | TIME | TEXT | EXPERIMENT |
|---|---|---|---|---|
| XIV.2.5 | Cell Division: Mitosis | | (Blue)<br>10-4 to 10-7 | |
| XIV.2.5a | | | (Blue)<br>Invest. 25 | |
| XIV.2.6 | Essential Features of Reproduction: Meiosis | | (Blue)<br>13-1 to 13-4 | |
| XIV.3 | Genes and Chromosomes | | | |
| XIV.3.1 | Seeking an Explanation for Mendel's Principles | | (Blue)<br>16-1 to 16-4 | |
| XIV.3.2 | The Chromosome Theory of Heredity | | (Blue)<br>16-5 to 16-10 | |
| XIV.3.3 | Further Light on Chromosomes | | (Blue)<br>16-11 to 16-14 | |
| XIV.4 | Origin of New Species | | | |
| XIV.4.1 | Changes in Genes | | (Blue)<br>17-1 to 17-5 | |
| XIV.4.1a | | | SG | Biological Effect of Irradiation on Seeds |
| XIV.4.1b | | | SG | Invisible Shield against Atomic Rays |
| XIV.4.2 | Genes and Populations | | (Blue)<br>17-6 to 17-8 | |
| XIV.4.3 | Populations in Transition | | (Blue)<br>17-9 to 17-12 | |
| XIV.4.3a | | | (Green)<br>Ex. 17.3 | Effect of Population Size: A Study in Human Evolution |
| XIV.4.3b | | | SG | Investigation: The Snow Goose |

| SECTION | TOPIC | TIME | TEXT | EXPERIMENT |
|---|---|---|---|---|
| XIV.4.4 | The Origin of New Types | | (Blue)<br>17-13 to 17-16 | |
| XIV.4.4a | | | SG | Investigation: Development of a New Breed of Laboratory Dog |
| XIV.5 | The Human Species | | | |
| XIV.5.1 | The Rise of Modern Man | | (Blue)<br>18-1 to 18-4 | |
| XIV.5.2 | The Genes of Man | | (Blue)<br>18-5 to 18-8 | |
| XIV.5.2a | | | (Green)<br>Ex. 17.4 | Sickle Cells and Evolution |
| XIV.5.2b | | | SG | Investigation: Genetics of Some Human Traits |
| XIV.5.3 | The Genetics of Human Population | | (Blue)<br>18-9 to 18-14 | |
| XIV.5.3a | | | (Green)<br>Ex. 17.2 | A Study of Population Genetics |
| XIV.5.4 | Changes in Human Populations | | (Blue)<br>18-15 to 18-18 | |
| XIV.5.4a | | | (Green)<br>Ex. 19.3 | Biological Distance |
| XV | Reproduction | 5 days | | |
| XV.1 | Essential Features of Reproduction | | (Blue)<br>13-1 to 13-4<br>(Review) | |
| XV.2 | Sexual Reproduction in Protists and Plants | | (Blue)<br>13-5 to 13-11 | |
| XV.2a | | | SG | Reproduction in Paramecium |

| SECTION | TOPIC | TIME | TEXT | EXPERIMENT |
|---|---|---|---|---|
| XV.2b | | | (Blue)<br>Invest. 30 | Reproduction in Flowering Plants |
| XV.3 | Sexual Reproduction in Animals | | (Blue)<br>13-12 to 13-17 | |
| XV.3a | | | SG | Sea Urchin Reproduction |
| XV.4 | Reproduction in Placental Mammals | | (Blue)<br>13-18 to 13-23 | |
| XV.4a | | | SG | A Mouse Colony for the High School Laboratory |
| XV.5 | Hormone Controls of the Reproductive System in Mammals | | (Blue)<br>13-24 to 13-27 | |
| XVI | Development | 15 days | | |
| XVI.1 | Problems of Development | | (Blue)<br>14-1 to 14-6 | |
| XVI.1a | | | SG | Chick Embryo Development |
| XVI.2 | Events of Development | | (Blue)<br>14-7 to 14-11 | |
| XVI.2a | | | (Green)<br>Ex. 15.5 | Development of an Embryo: Frog |
| XVI.2b | | | (Green)<br>Ex. 14.1 | Animal Structure and Function: The Frog |
| XVI.3 | Explanations of Development | | (Blue)<br>14-12 to 14-16 | |
| XVI.4 | Unusual Kinds of Development | | (Blue)<br>14-17 to 14-20 | |
| XVI.4a | | | (Green)<br>Ex. 15.1 | Vegetative Reproduction: Regeneration (Animal) |

| SECTION | TOPIC | TIME | TEXT | EXPERIMENT |
|---|---|---|---|---|
| XVI.5 | Regulation in Plants | | (Blue)<br>24-1 to 24-3 | |
| XVI.5a | | | SG | Plants on a Phonograph |
| XVI.5b | | | (Green)<br>Ex. 18.3 | Tropisms |
| XVI.5c | | | (Blue)<br>Invest. 33 | Investigation: Patterns of Growth in Plants |
| XVI.5d | | | (Blue)<br>Invest. 51 | Investigation: Regulation of Growth in Plants |
| XVI.5e | | | (Blue)<br>Invest. 32 | Investigation: Growth Curves |
| XVII | The Integrated Organism and Behavior | 6 days | | |
| XVII.1 | The Biology of Behavior | | (Blue)<br>27-1 to 27-3 | |
| XVII.1a | | | SG | Unusual Plant Behavior |
| XVII.1b | | | (Green)<br>Ex. 18.2 | Photoperiodic Control of Plant Behavior |
| XVII.1c | | | (Green)<br>Ex. 12.5 | Some Characteristics of Living Matter |
| XVII.1d | | | (Green)<br>Ex. 9.3 | Effects of Salinity of Living Organisms |
| XVII.2 | Animal Behavior | | (Blue)<br>27-4 to 27-9 | |
| XVII.2a | | | (Green)<br>Ex. 14.3 | A Heart at Work |
| XVII.2b | | | SG | Responses of Sow Bugs |
| XVIII | Populations | 8 days | | |

| SECTION | TOPIC | TIME | TEXT | EXPERIMENT |
|---|---|---|---|---|
| XVIII.1 | The Population Concept | | (Blue)<br>28-1 to 28-5 | |
| XVIII.1a | | | SG | Space versus Population in Drosophila |
| XVIII.1b | | | (Green)<br>Ex. 2.1 | Population Growth: A Model |
| XVIII.1c | | | (Green)<br>Ex. 2.2 | Study of a Yeast Population |
| XVIII.1d | | | (Green)<br>Ex. 2.3 | Factors Limiting Populations |
| XVIII.1e | | | SG | Human Populations |
| XVIII.2 | Some Population Problems | | (Blue)<br>28-6 to 28-8 | |
| XVIII.2a | | | SG | Investigation: The Effect of Crowding on Populations |
| XVIII.2b | | | SG | Paramecium Competition |
| XIX | Societies | 5 days | | |
| XIX.1 | The Structure of Societies | | (Blue)<br>29-1 to 29-4 | |
| XIX.2 | Social Adaptations | | (Blue)<br>29-5 to 29-9 | |
| XX | Communities | 20-35 days | | |
| XX.1 | The Structure of Communities | | (Blue)<br>30-1 to 30-5 | |
| XX.1a | | | (Green)<br>Ex. 8.1 | Limiting Factors in Distribution |
| XX.1b | | | SG | Layering in a Hay Infusion |

| SECTION | TOPIC | TIME | TEXT | EXPERIMENT |
|---|---|---|---|---|
| XX.2 | The Functions of a Community | | (Blue) 30-6 to 30-10 (30-6 to 30-8 will be a review) | |
| XX.2a | | | (Blue) Invest. 60 | Tracing a Food Chain |
| XX.2b | | | (Blue) Invest. 61 | Transport of Phosphate in Plants |
| XX.2c | | | SG | Investigation: Sewage Plant Food Web |
| XX.2d | | | SG | Investigation: Isle Royale Study |
| XX.2e | | | SG | Symbiotic Relationship between Termites and Flagellates |
| XX.2f | | | (Green) Ex. 8.3 | Effects of Fire on Biomes |
| XX.2g | | | (Green) Ex. 9.2 | Succession in Fresh-water Communities: A Laboratory Study |
| XX.2h | | | SG | Investigation: Biogeography of Oregon |
| XX.3 | A Study of a Community | | (Blue) pp. 663-667 | |
| XX.3a | | | | Field Study Projects |

## - Chapter XII: Energy Transfer Within Communities -

### XII.1 - COMMUNITY ENERGY EXCHANGE

Exchange of energy within a plant and animal community is the essential process which maintains that community. A community such as a pond, a field or a forest near your home functions through the never-ending process of energy transfer, much of which is in the form of food production by plants or food consumption by animals. A community such as your home, a small town or large city may be studied as a series of energy transfers.

Basic to all such energy transfer is the source of that energy. Examine these two partial food chains:

leaves → grasshopper → frog → snake → hawk →
or
grass → cow → milk → you →

In these food chains the source of the food energy originated in a green plant, the leaves or grass. Tracing any food chain to its beginning will

100

lead you to a green plant. Even in a community such as a dark cave with its eyeless salamanders, bats, insects and non-green fungi, a link can be found to the outside world where food energy is brought into that cave from some outside source originating in a green plant. No cave community exists without this link to the outside.

The plant then becomes the primary producer of food for all living organisms. But where does this energy originate in the green plant? Again transfer of energy is involved. In the process called photosynthesis, energy from the sun is converted to food energy within the green plant. The word itself ("photo" referring to light, and "synthesis" referring to putting together) means the uniting of carbon dioxide and water that with the aid of light energy forms a food we know as sugar. So despite the fact that the food chains begin with a green plant, there was a transfer of energy from an outside source into the food chain.

A series of experiments follow which will give you a better understanding of this energy transfer in a community. They will also introduce the process of photosynthesis and will show some transfer of materials between organisms.

## XII. 1a - Experiment: ENERGY EXCHANGE IN A HUMAN COMMUNITY

On a chart similar to the one below make a detailed listing of all sources of useful energy which flow into your home and all sources flowing out in a 24-hour period.

INFLOW

| Energy Source | Energy Type |
|---|---|
| | |

OUTFLOW

| Energy Source | Energy Type |
|---|---|
| | |

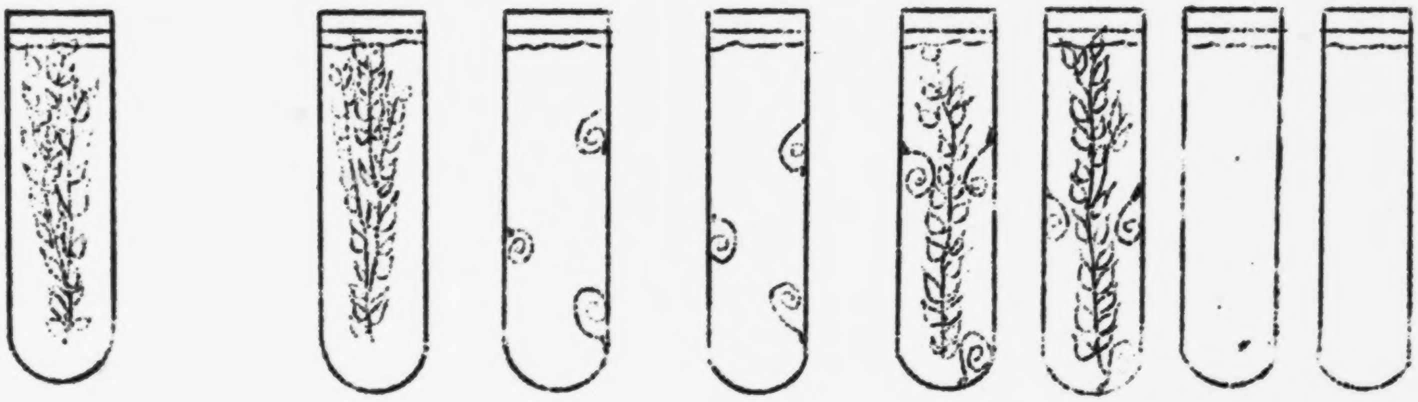
Summarize the energy transfer within your home. Which are luxuries? Which are essential for your well-being?

## XII.2 - FOOD CHAINS AND FOOD WEBS: TRANSFER OF ENERGY AND MATTER IN A COMMUNITY

Read sections 30-6 to 30-8, Blue text.

## XII.2a - Experiment: PLANT AND ANIMAL RELATIONSHIPS

Set up the following series of test tubes with bromthymol blue solution, elodea and snails. Seal each and place near a window.



| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Bromthymol blue | BB | BB | BB | BB | BB | BB | BB |
| Water | Water | Water | Water | Water | Water | Water | Water |
| ________ | $CO_2$ | ____ | $CO_2$ | ____ | $CO_2$ | ____ | $CO_2$ |
| Elodea | Elodea | ____ | ____ | Elodea | Elodea | ____ | ____ |
| ________ | ____ | 3 Snails | 3 Snails | 3 Snails | 3 Snails | ____ | ____ |

Set up an identical set of test tubes as above but place these in complete darkness.

Observe all tubes the following day and write several sentences about each test tube and its contents, explaining what has happened in each case

## XII.3 - THE NATURE OF PHOTOSYNTHESIS

Read sections 9-5 to 9-7, Blue text.

### XII.3a - Experiment: RELEASE OF OXYGEN DURING PHOTOSYNTHESIS

Bubbles of oxygen escape from the cut stems of elodea sprigs placed in bright sunlight.

To show this, invert a 3-inch tip of a vigorously growing elodea sprig into a test tube or beaker containing aquarium water to which about 2 cc of a 0.25 per cent solution of sodium bicarbonate has been added for every 100 cc of aquarium water (the water has been boiled to drive off dissolved gases, and then cooled). The bicarbonate will provide a source of carbon dioxide since the small quantity of carbon dioxide ordinarily found in aquarium water acts as a limiting factor in photosynthesis. Tie the sprig to a glass rod then immerse in the container so that it will be held down in place.

The plant should be exposed to a light source. Shortly thereafter, the number of bubbles of oxygen escaping from the cut stem per minute may be counted.

Place a lamp two meters away from the test tube and after several minutes count the number of bubbles released in 1 minute. Repeat this with the lamp at 1 meter distance and again at 50 cm, 30 cm, 10 cm distances and then with direct contact between the test tube and the lamp. Record and graph your results. Is light a factor in photosynthesis?

You may not believe that the gas being released is really oxygen. Using the funnel method as shown in FIG. XII.1, collect this gas and test for identification.

### XII.3b - Experiment: THE ROLE OF PIGMENTS AND LIGHT IN PHOTOSYNTHESIS.

Coleus plants often contain several pigments which may or may not be necessary in food production. Pick a coleus leaf containing both red and green pigments.

Draw this leaf, indicating the pattern of pigment colors of the leaf.

Boil this leaf in water for several minutes and again draw the leaf indicating the pigment colors of the leaf.

Boil the leaf again, this time in alcohol until all color is removed. Again draw the leaf.

Place the leaf in a petri dish and cover with iodine, a starch indicator solution. After several minutes again draw the leaf. Compare your drawings.

Which patterns are identical? What conclusions can you form from this experiment? Which of the pigments is water soluble? Which is alcohol soluble?

Repeat the above experiment only this time use a coleus leaf from a plant which has been in the dark for 10 days. Again compare your drawings. Which patterns are identical? What conclusions can you form from this experiment?

## XII.4 - STRUCTURE OF MULTICELLULAR PLANTS IN RELATION TO PHOTOSYNTHESIS

Read sections 19-4 to 19-8, Blue text.

### XII.4a - Experiment: CHLOROPLASTS IN ELODEA PLANTS.

The chlorophyll in leaves is found in small bodies called chloroplasts. These are located in the cytoplasm of green plant cells. One of the best plants in which to examine chloroplasts is a vigorously growing elodea.

Mount a leaf from the growing tip in a drop of aquarium water with slide and cover slip and examine under low and high power. When the leaves from young, growing tips are examined, the chloroplasts may appear to be moving in the cytoplasm of the cells. In reality, it is the cytoplasm which is circulating; the chloroplasts are being carried by the moving "stream" of cytoplasm.

Little is known about the streaming cytoplasm but energy is no doubt required within this cell to bring about these movements. Draw and label the leaf and cell parts as you see them.

- Chapter XIII: The Variety of Living Things -

## XIII.1 - CLASSIFYING LIVING THINGS

Read sections 2-1 to 2-8, Blue text.

### XIII.1a - Experiment: CLASSIFYING LIVING THINGS

Because of the vast number of objects around him, man has, over the years, found it convenient or even necessary to group or classify similar things together for purposes of reference, study and demonstration of relationships. We do this almost unconsciously in our everyday world. For example, when we speak of an "automobile," we would be referring to a member of a whole class of things possessing certain characteristics. For many purposes we do not need to have individual names for each separate member of the group in order to communicate various ideas to other people. Of course, within a group there may be subgroups, sub-subgroups, and so on.

Using our automobile example, we might wish to refer more specifically, say, to sedans, convertibles or "hard-tops"; each of these categories could be subdivided into color groups.

For other purposes we may find it more useful to group our automobiles not by body style but by brand name, age or some other way. In any event, it is a great advantage to have group names for objects around us.

So it is with the bewildering diversity of living forms. It has become necessary to group the kinds of living things into a hierarchical order of classification based upon observation of the organisms. You have already been introduced to the difficulties of classification in sections II.29 and II.30. In this exercise you will obtain further practice in recognizing groups and subgroups of objects and in erecting a scheme of classification which can be compared with those of your classmates.

Spread the contents of the box of items given you and your partner on the laboratory bench. Let us call the entire group of objects "pile A." Separate pile A into two major groups so that all members of each separate set or group have some characteristic in common. This characteristic might be color, shape, size, material or something else. Call one group "pile B" and the other group "pile C." Record on the chart provided on page 277 the contrasting characteristic you used to segregate pile A (left-hand column) into the two groups (right-hand column). Put pile C aside for the moment and examine more closely the objects you placed in pile B. Select a characteristic which will separate the items of this major group into two sets. Call these "pile D" and "pile E" and record this determination on the chart directly below the first entries opposite "Groups to be divided 'B'." Now look at the objects in pile D. Again select a characteristic which differentiates between these items, label the groups appropriately and enter "Groups to be divided," "Characteristic" and "Resulting groups" on the chart. Continue in this manner until the "groups" have only one item in them. When this point has been reached, enter the name of the object under "Resulting groups" rather than giving it a letter designation. Return to group E and proceed as you have done for group D. Return to those items you originally placed in group C and separate these in the way you have those in group B.

When you have finished this task, you have not only classified the items into a hierarchical system, you have also made a dichotomous key on your chart. Such a key is a very valuable tool for biologists to use in identifying unfamiliar organisms. To become familiar with how this is done, select any one of the items which you have

| Groups to be divided | Characteristic | Resulting groups |
|---|---|---|
| A | | B |
| | | C |
| B | | |
| | | |
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just classified and compare it with the first pair of contrasting characteristics listed on your "key." Does it belong in group B or group C? If it is the latter, go down your chart to where the group to be divided is C and again compare against the two contrasting characteristics. Continue in this manner and, unless you have made an error in your key (or in your "keying"), you will ultimately arrive at the name of the object. Keys are such useful tools to the biologist that you will find many opportunities to use them in the future.

Looking at the entire assemblage of items once again, can you see a pattern of dichotomies different from the one you used which would also classify the objects? Compare your classification and key with those of other teams in the laboratory. Are they all alike? Which one is "correct"? Which one is "best"?

## XIII.2 - THE KINDS OF LIVING THINGS -- ANIMALS

Refer to appendix, pp. 677-682,

Blue text.

### XIII.2a - Experiment: STRUCTURAL CHARACTERISTICS IN THE CLASSIFICATION OF ANIMALS (Ex. .1 Green)

## XIII.3 - THE KINDS OF LIVING THINGS -- PLANTS

Refer to appendix, pp. 675-677,

Blue text.

### XIII.3a - Experiment: DIVERSITY IN THE PLANT KINGDOM (Ex. 5.1 Green)

### XIII.3b - Experiment: DIVERSITY AMONG ANGIOSPERMS (Ex. 5.2 Green)

## XIII.4 - THE KINDS OF LIVING THINGS -- PROTISTS

Refer to appendix, pp. 673-675.

## XIII.4a - Experiment: LIVING THINGS IN POND WATER

Among the many subjects studied by the early biologist, Antony Van Leeuwenhoek, was common pond water. The excitement which he felt when he discovered this hitherto unknown microscopic world can be repeated today in the laboratory. You will be amazed, as he was, at the swarming life which exists, unobserved, beneath our very noses.

With a dropper, place a drop of pond water (selected from near the bottom of the pan) on the middle of a clean microslide. Carefully lower a cover slip into place and observe carefully under the microscope. Record your observations in the accompanying table.

| Table of Observations | |
|---|---|
| Number of objects in a microscope field (one) | |
| Number of living things in a microscope field (one) | |
| Number of different ways of moving | |
| Number of different shapes | |
| Length and breadth of smallest organism | |
| Length and breadth of largest | |

What kinds of things can you see? Are all of them living? What fraction of things appear to be non-living? How do you decide which are living and which are non-living? How many different things are moving? Do they move in different ways? Do you see any unmoving things which you believe to be alive? How many different shapes of living things can you find? Sketch the various shapes of organisms. What is the apparent size of the largest and smallest moving things? What would be the actual sizes of these organisms? Can you identify any of the organisms as plants? As animals? Compare your sketches and direct observations with the pictures of protists in the textbook. How many of these groups can you identify on your slide? Why do biologists put protists in a major group by themselves? Might there be other ways of classifying living things? Explain.

## XIII.4b - Experiment: THE ABUNDANCE OF AIR-BORNE MICROORGANISMS IN VARIOUS SCHOOL ENVIRONMENTS (Ex. 7.7 Green)

## XIII.4c - Experiment: EFFECT OF TEMPERATURE ON GROWTH OF MICROORGANISMS

Bacteria and other microorganisms are very common inhabitants of a wide range of different habitats. Yet each organism may be able to live in only a very restricted environment or under special conditions since it is affected by various environmental factors. Among the more important such conditions affecting microbial growth are temperature, food supply, moisture, oxygen, acidity and the presence or absence of other organisms.

In this exercise you will gain some knowledge of the kinds of protists normally living in milk and become familiar with the effect that temperature has upon these organisms.

Place 30 ml of raw (unpasteurized) skim milk in each of four sterile test tubes and label these tubes U-1 (for "unheated, number 1"), U-2, U-3 and U-4 with a marking pencil. Put tube U-1 in a test tube rack and store in a refrigerator held at about 7° C; put tube U-2 in a test tube rack and leave at room temperature (22-23°C); put tube U-3 in a test tube rack in an incubator with a temperature at 37° C; and tube U-4 in a rack in an incubator held at about 45° C.

Place 30 ml of the raw milk in each of a second series of four sterile test tubes. Heat the filled tubes in a water bath for thirty minutes at 62° C. Label these tubes W-1 (for "warmednumber 1"), W-2, W-3, and W-4. Incubate each tube as you did above.

Finally, fill four additional sterile test tubes with 30 ml of raw milk each and heat them for ten minutes in a 90° C water bath. Label these tubes H-1 (for "hot--number 1"), H-2, etc. Incubate as directed above.

Each day for a week check the test tubes of milk for changes in appearance. Record your observations of changes in appearance and the number of days required for the changes to appear on a chart which shows the treatment of milk and the temperatures of incubation.

What happened to the milk when it changes in appearance? What has caused this change?

On successive days examine the samples of milk for microorganisms. It has been found that the following procedure will stain the small protists that may be living in the milk:

— Place a small drop of milk on a very clean microslide and spread it thinly over an area of about 1 cm in diameter.

— Let the drop dry in the air to form a film on the slide.

— Pass the slide, film-side up, quickly through the flame of a bunsen burner to stick the microorganisms to the slide.

-- After the slide has cooled to room temperature, dip it into a glass of clean water.

-- Remove the slide and, while it is still wet, place two or three drops of crystal violet stain over the film.

— After fifteen to twenty seconds, pour off the excess stain and rinse the slide gently in clean water.

-- Rinse again in another glass of clean water and drain the water from the slide by placing a corner on a piece of paper toweling.

— Allow the film to dry before examining under the compound microscope.

What microorganisms are present? Can you identify different morphological shapes of bacteria? Why are bacteria placed in the Kingdom Protista? In what tubes are microorganisms most abundant? Why has the milk usually purchased in a store been subjected to heating? What is this process called?

What temperature range does your data indicate would be best for reducing microorganismal growth?

What temperature range appears to be optimal for growth of milk-inhabiting organisms?

At what temperatures are these protists killed by the techniques of this procedure?

Make a general statement about the effects of temperature on growth of microbes in milk.

# - Chapter XIV: Descent with Modification -

## XIV.1 - THE MEANS OF EVOLUTION: TWO CONFLICTING VIEWS

### XIV.1.1 - VIEWS ON EVOLUTION BEFORE DARWIN'S TIME

Read sections 3-1 & 3-2, Blue text.

### XIV.1.2 - DARWIN'S THEORY OF THE MEANS OF EVOLUTION.

Read sections 3-3 to 3-8, Blue text.

### XIV.1.3 - ADAPTATIONS AND SELECTION

Read sections 3-9 to 3-11, Blue text.

### XIV.1.3a - Experiment: PALEONTOLOGICAL COMPARISON

(Ex. 10.1 Green)

## XIV.1.3b - Investigation: NATURAL SELECTION OBSERVED.

(Invest. 9 Blue)

## XIV.1.4 - THE ORIGIN OF LIVING THINGS

Read sections 4-1 to 4-10, Blue text.

### XIV.1.4a - Experiment: SPONTANEOUS GENERATION

(Ex. 6.2 Green)

## XIV.2 - PATTERNS OF HEREDITY

### XIV.2.1 - HEREDITY ENVIRONMENT

Read sections 15-1 to 15-4, Blue text.

### XIV.2.1z - Experiment: HEREDITY AND ENVIRONMENT

### XIV.2.2 - THE WORK OF MENDEL

Read sections 15-5 to 15-7, Blue text.

### XIV.2.2a - Experiment: SOYBEAN AND CORN GENETICS: MENDEL'S APPROACH

You will be asked to develop the hereditary pattern of corn and soybeans in much the same way as Mendel did when he developed the heredity pattern of peas over one hundred years ago. He knew nothing of the mechanisms of genes and chromosomes yet his experiments and conclusions have been supported remarkably well by modern-day genetics.

Using three different ears of corn and a flat of developing soybean plants your teacher will supply, count and complete the following table:

| | Dark Green | Light Green | Yellow |
|---|---|---|---|
| # of Soybeans | | | |

| | Yellow | Purple | | |
|---|---|---|---|---|
| # of Kernels Corn ear 1 | | | | |
| # of Kernels Corn ear 2 | | | | |

| | purple-smooth | purple-wrinkled | yellow-smooth | yellow-wrinkled |
|---|---|---|---|---|
| # of Kernels Corn ear 3 | | | | |

Exercise for Home, Desk and Lab (HDL)

(1) What ratio of purple to yellow kernels was found in corn ear #1?

(2) What colors were the probable parents of this ear of corn?

(3) What alleles were probably present in each of the parent ears of corn?

(4) What alleles are probably present in the yellow kernels found on corn ear #1?

(5) What alleles are probably present in the purple kernels found on corn ear #1?

(6) Which color is dominant?

(7-12) Answer the above questions for corn ear #2.

(13) What ratio of purple-smooth to purple-wrinkled to yellow-smooth to yellow-wrinkled was found on corn ear #3?

(14) What is the probable genotype of the yellow-wrinkled corn?

(15) You cannot be sure of the alleles present in the purple-smooth corn. Why? Of the four alleles present, which do you know?

(16) What color and probable coat condition did the parents of corn ear #3 have?

(17) Is wrinkled or smooth dominant?

(18) What ratio was obtained in the soybean plants of dark green to light green to yellow?

(19) What color is dominant?

(20) What alleles are present in each of the different colored soybean plants?

(21) What color were the parent plants of this set of soybeans?

(22) How do you justify any deviation from the expected ratio to the ratio you actually counted in each of the above genetic samples?

(23) How could you improve the accuracy of your ratios?

## XIV.2.3 - PROBABILITY AND GENETICS

Read sections 15-8 to 15-12, Blue text.

## XIV.2.31 - Experiment: PROBABILITY

(Ex. 16.2 Green)

As your teacher directs, expand the score sheet for one-penny tosses to an extra column and the two-penny tosses to two extra columns.

After answering the questions in the lab book, relate the coins to the offspring counts you made on the corn ears. The single penny tosses should be related to all counts except corn ear #3 which relates to the two penny tosses. Using heads for the dominant purple allele, how does your ratio of pennies compare to the actual corn ear #1 ratio? To the corn ear #2 ratio? Using heads for green and tails for yellow, how does the penny ratio compare to the actual soybean ratio? Using the two penny tosses with the first two columns, heads as dominant purple and the second two columns, heads as dominant smooth, how does the penny ratio compare to the actual counted ratio on corn ear #3?

## XIV.2.4 - HEREDITARY PATTERNS

Read sections 15-13 to 15-17,

Blue text.

## XIV.2.4a - Experiment: HUMAN BLOOD GROUPS

(Ex. 19.2 Green)

After typing your blood and answering the questions in the lab book, you are now ready to determine the genetic factors involved in blood types. A and B alleles are dominant while O is a recessive allele. Therefore, assuming that every person has two alleles for his blood type, six combinations may occur resulting in the four known blood types. They are as follows:

AA)
AO) A type blood

BB)
BO) B type blood

AB) AB type blood

OO) O type blood

We cannot directly determine the genotype of an A or a B blood-type person because we have no known means to determine the second allele which is carried. It may be an identical allele or the recessive O allele. Likewise, we are sure of the genotype of those people with either O or AB blood. We can, however, often determine the second allele of an A or B blood-type person by examining the blood types of his parents and/or children.

Exercises for Home, Desk and Lab (HDL)

Examples: (1 and 2)

(1) If a man with A type blood marries a woman of O type blood and they have 5 children, all of blood type A:

- (a) What is the most probable genotype of the man?
- (b) What is the genotype of the woman?
- (c) Of the children?

(2) A friend of yours has B type blood. He knows his mother has O type blood.

- (a) Immediately, you know the genotype of his blood is?
- (b) What genotypes of blood might his father have

With this basic information, find probable solutions to the following genetic problems:

(3) What blood types might possibly result in children of a family whose mother has B blood and whose father, AB blood?

(4) Suppose a father of blood type A and a mother of type B have a child of type O. What types are possible in their subsequent children?

(5) Suppose a father of type B and a mother of type O have a child of type O. What are the chances that their next child will be type O? Type B? Type A? Type AB?

(6) When one parent is blood type AB and the other is type O, how many times in families with three children would you expect one child of type A and two children of type B?

(7) Assuming you do not know the blood type of your future husband or wife but now know yours after the blood typing lab, what blood types might you possibly expect your children to have? What blood types can't they possibly have?

(8) Two type AB parents took home a newly born type A baby from the hospital and decided it was not their baby because it did not seem to resemble either parent. They claimed another couple had their baby. The other parents were both type A and took home a type O baby. If you were the judge in this case, what would be your decision in this dispute? Why?

(9) You are the judge in a case in which a type O man claimed a $50,000 inheritance after the death of type A and type AB parents.

(a) What would be your decision? Explain.

(b) What if the man had Type B blood? Explain.

## XIV.2.5 - CELL DIVISION: MITOSIS

Read sections 10-4 to 10-7, Blue text.

### XIV.2.5a - Investigation: CELL DUPLICATION

(Invest. 25 Blue)

### XIV.2.6 - ESSENTIAL FEATURES OF REPRODUCTION: MEIOSIS

Read sections 13-1 to 13-4, Blue text.

## XIV.3. GENES AND CHROMOSOMES

### XIV.3.1 - SEEKING AN EXPLANATION FOR MENDEL'S PRINCIPLES

Read sections 16-1 to 16-4, Blue text.

### XIV.3.2 - THE CHROMOSOME THEORY OF HEREDITY

Read sections 16-5 to 16-10, Blue text.

After reading the above sections, test your understanding on the following problems. You may also want to review Chapter 15 before you begin. These problems begin with simple Mendelian genetics and become more complex towards the end. These basic notations will be used:

$F_1$ means 1st generation

$F_2$ means 2nd generation

$P_1$ means parents of 1st generation

Any capital letter means a dominant gene.

Any small case letter means a recessive gene

Pure means both genes of an organism for a particular trait are identical (homozygous)

Hybrid means genes of an organism for a particular trait are different (heterozygous)

Phenotype means the physical or outward appearance of an organism for a particular trait. (example: tall, green, or blue-green)

Genotype means the actual 2 genes of an organism for a particular trait (example: Tt, GG, or bb)

**Exercise for Home, Desk and Lab (HDL)**

(1) Cross a pure black guinea pig with a pure white guinea pig and determine the offspring for the first and second generations. Black is dominant.

|   | b | b |
|---|---|---|
| B |   |   |
| B |   |   |

$F_1$

|   | B | b |
|---|---|---|
| B |   |   |
| b |   |   |

$F_2$

In the first generation there are_____black pigs,_____white pigs, _____hybrid pigs. In the second generation there are_____hybrid pigs, _____pure pigs,_____black pigs,_____ white pigs,_____hybrid black pigs, _____hybrid white pigs,_____pure black pigs.

(2) If a pure long-eared rabbit was mated to a pure short-eared rabbit, what are the genotypes and phenotypes of $F_1$ and $F_2$ if long-eared is dominant?

|   |   |   |
|---|---|---|
|   |   |   |
|   |   |   |

|   |   |   |
|---|---|---|
|   |   |   |
|   |   |   |

| Phenotypes: | Genotypes: | |
|---|---|---|
| ___F1 Long-eared | ___$F_1$ Hybrid short, | ___$F_2$ Hybrid short |
| ___$F_1$ Short-eared | ___F1 pure short, | ___$F_2$ pure short |
| ___$F_2$ Long-eared | ___$F_1$ Hybrid long, | ___$F_2$ Hybrid long |
| ___$F_2$ Short-eared | ___$F_1$ pure long, | ___$F_2$ pure long |

(3) Mate a pure wingless fruit fly to a fruit fly with pure wings if having wings is dominant. What are the $F_1$ and $F_2$ phenotypes and genotypes?

(4) Explain and show how you would make a cross to determine if a tall corn stalk was pure or hybrid.

(5) A lobe-eared man and a non-lobe-eared woman have 8 children of which 4 are lobe-eared and 4 are non-lobe-eared. What are the genotypes of the man, the woman, the lobe-eared children and the non-lobe-eared children if lobe-eared is dominant? Show your work.

(6) Normal-skinned hybrid human x normal-skinned hybrid human -- what are the possible phenotypes for albinism?

(7) Normal pure-bred garter snake x albino garter snake -- what are the phenotypes and genotypes of $F_1$ and $F_2$ for albinism?

(8) What are the probable genotypes of all people in this cross for albinism?

Albino X Normal
↓
9 Normal Children

(9) What are the genotypes of all people in this cross for albinism?

Normal x Albino     Normal x Normal
↓     ↓
Normal     Albino
x
↓
2 Normal
1 Albino

(10) A family has 7 girls. What are the chances that the next child would be a boy?

(11) If a red 4 o'clock were crossed with a white 4 o'clock, give the genotypes and phenotypes of $F_1$ and $F_2$ if neither red nor white is dominant.

(12) Mate a white cow and a red bull and tell what the second generation looks like if neither color is dominant.

(13) How would you determine the genotypes of a white, a red and a roan herd of cows.

(14) In radishes, the shape may be long or round or oval. Crosses between long and oval gave 159 long, 156 oval. Crosses between round and oval gave 199 round, 203 oval. Crosses between long and round gave 576 oval. Crosses between oval and oval gave 121 long, 243 oval, 119 round. What type of inheritance is involved?

(15) In foxes, a pair of genes P and p interact as follows: PP is lethal, usually dying during embryonic life; Pp results in platinum color, and pp produces silver foxes. Could a fox breeder establish a true-breeding variety of platinum foxes?

(16) When platinum foxes are crossed together, the offspring usually appear in the ratio of 2 platinum to 1 silver. Occasionally, however, a pure white pup

appears from such matings, but invariably dies after a few hours or days. What is the probable explanation of the white pups?

(17) How many different kinds of gametes could be produced by a guinea pig of the formula bbLlRrSs?

(18) If a male guinea pig of the formula BbLlRrSs were mated to a female of the formula bbllrrss, how many different kinds of sperms would be produced by the male? How many different kinds of eggs would be produced by the female?

* * *

The expression of baldness varies with the sex of an individual. Basically, two dominant alleles, BB, will produce a child who will not lose hair while two recessive alleles, bb, produce baldness (other genes determine how bald you will become and when you will become bald). The hybrid for baldness, Bb, expresses itself differently by being non-bald in females and bald in males.

This has been theoretically explained as a masking of the dominant B allele in males by the male hormone testosterone so that only the remaining recessive b allele will express itself.

| Female | Male |
|---|---|
| BB)<br>Bb) hair | BB) hair |
| bb) bald | Bb)<br>bb) bald |

(19) A bald man whose father was not bald marries a non-bald woman whose mother was bald. What are the genotypes of these two people in regard to the genes for baldness and non-baldness? What kinds of children can they have in regard to these characters?

(20) A non-bald man marries a non-bald woman. They have a son and a daughter. At the age of thirty-five, the son becomes bald. What are the chances that the daughter will also become bald because of her genetic constitution?

(21) A recent issue of the Oregon Journal ran the following column:

DEAR ANN LANDERS: Please don't consider me crazy for asking you this but I need help badly and you are my only hope.

My mother is bald. My father has a very heavy head of hair. My older brother is rapidly losing his hair and will soon be bald -- like my mother.

I am a circus acrobat. Hanging by my hair is part of my act. My hair seems to be the same heavy type that father has, but at times I become depressed worrying about the possibility that perhaps my hair will fall out like my mother's.

Should I change professions before it is too late? Thank you for your kind consideration. - WORRIED.

DEAR WORRIED: Don't be a coward and change professions, even if you should detect signs of baldness. Stick with it. Bill yourself as the world's only balding acrobat who hangs by his hair. And please -- don't chicken out and use a net. I'd like to get rid of you characters who write phony letters -- and the sooner the better.

What are the genotypes of the brother, mother, father and the girl who wrote the letter? Which of the 4 family members will lose their hair? How would you advise her?

* * *

White eyes in a fruit fly is a sex-linked recessive characteristic. Tell the genotypes and phenotypes of the $F_1$

and $F_2$ generations as well as if each phenotype is ♀ or ♂ in the following matings.

(22) ♀ white-eye x ♂ red-eye -- both pure.

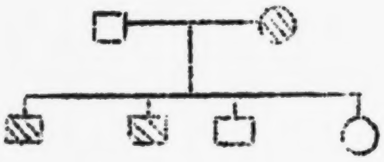
(23) ♂ white-eye x ♀ red-eye -- both pure.

(24) Hemophilia in humans is sex-linked. Show if the male or female is the carrier of this disease and also explain who (male or female) is more likely to get the disease.

(25) Two normal-visioned parents produce a color-blind son. What are the genotypes of the parents? What are the chances of their next child being a color-blind daughter?

(26) Alligator skin only occurs in males. If a father has this skin abnormality, his sons always also get alligator skin. Why? Could it be due to a simple recessive gene? Could it be due to a simple dominant gene?

(27) In the accompanying human pedigree, a certain character is represented by the solid squares and circles. Answer the following questions about this character:



(a) Could this be a sex-influenced character due to a gene dominant in males and recessive in females (such as baldness)?

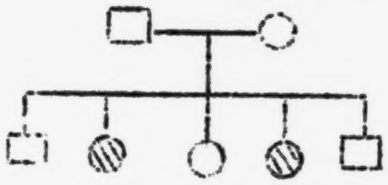
(b) Could the character in the foregoing pedigree be due to a simple dominant gene?

(c) Could it be due to a simple recessive gene?

(d) Could it be due to a recessive sex-linked gene?

(e) Could it be due to a dominant sex-linked gene?

(28) A second human pedigree is illustrated in the accompanying diagram. Answer the following questions about the character shown by solid symbols:



(a) Could this be a sex-influenced character due to a gene dominant in males and recessive in females (such as baldness)?

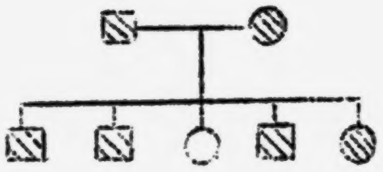
(b) Could it be due to a sex-linked recessive gene?

(c) Could it be due to a sex-linked dominant gene?

(d) Could it be due to a simple recessive gene?

(e) Could it be due to a simple dominant gene?

(29) The accompanying diagram illustrates a third human pedigree. Again answer the following questions about the character shown:



(a) Could this be a sex-influenced character due to a gene dominant in males and recessive in females (such as baldness)?

(b) Could it be due to a sex-linked recessive gene?

(c) Could it be due to a sex-linked dominant gene?

(d) Could it be due to a simple dominant gene?

(e) Could it be due to a simple recessive gene?

### XIV.3.3 - FURTHER LIGHT ON CHROMOSOMES

Read sections 16-11 to 16-14, Blue text.

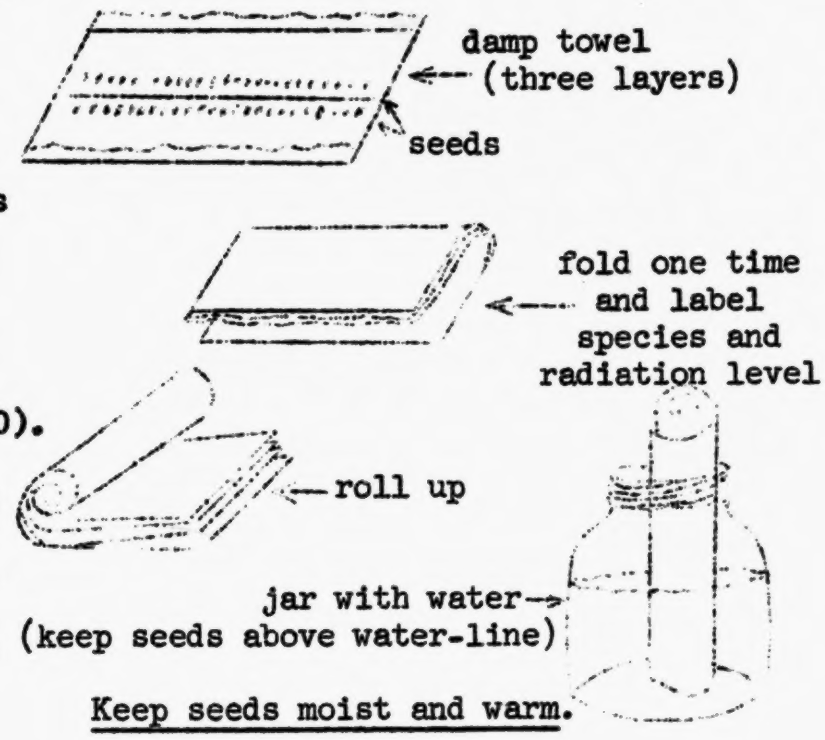
## XIV.4 - ORIGIN OF NEW SPECIES

### XIV.4.1 - CHANGES IN GENES

Read sections 17-1 to 17-5, Blue text.

### XIV.4.1a - Experiment: BIOLOGICAL EFFECTS OF IRRADIATION ON SEEDS

After reading the assignment, you may be thinking about monstrous mutations and all manner of Hollywood versions of the real world. Let's take a look at a situation involving the interaction of radiation and a living system.


damp towel
(three layers)
seeds
fold one time
and label
species and
radiation level
roll up
jar with water
(keep seeds above water-line)

Keep seeds moist and warm.

FIG. XIV.1 - Seed Doll

You will be provided with seeds (rye and other species) which have been exposed to varying amounts of radiation (gamma rays from cobalt 60). As a class, make a one-hundred-seed paper towel "Seed Doll" germination pack for each species and radiation level.

Each day count the number of sprouted and the number of unsprouted seeds. (You will have to come to some kind of agreement as a class about what is meant by the term "sprouted." If you do not, you will be unable to rely on the observations of other members of the class.)

After counting and recording for three to four days, each student should select one sprouting rye seed from each irradiation level and plant it as illustrated in FIG XIV.2.

Try to select seedlings which seem to be pretty much in the same condition. Keep a daily record of the length of the seedlings and, if you need to, go to the instructor for a replacement sprout. It is probable that most of the plants will stop growing in about three weeks. You should maintain records until it is clear that growth in length has stopped or become insignificant.

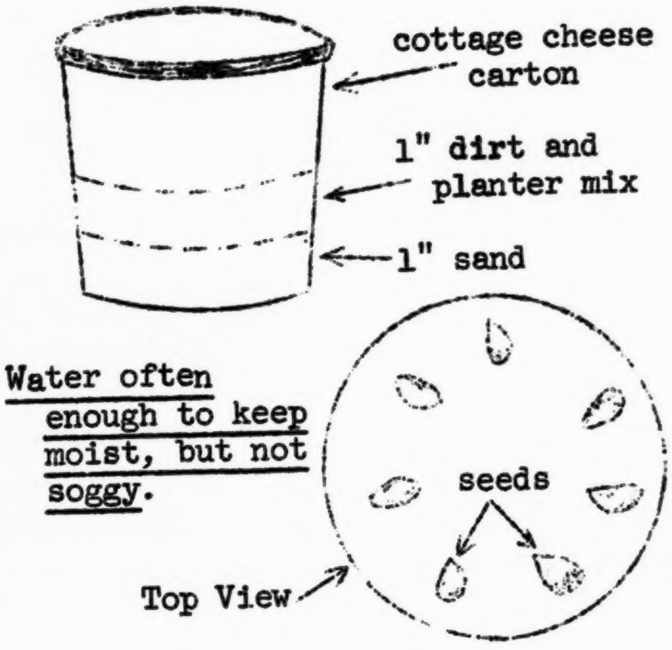

cottage cheese carton
1" dirt and planter mix
1" sand
Water often enough to keep moist, but not soggy.
seeds
Top View

FIG. XIV.2

There are many questions which can be answered by such an array of data as the class is building up.

How could you use the data to show whether or not: (1) irradiation kills seeds; (2) irradiation affects the ability of seeds to sprout; (3) irradiation delays sprouting in someway without killing the seeds; (4) irradiation shortens the number of days which a seed spends growing; (5) irradiation slows down the growing process? You might be able to see others.

As you develop a group of questions which you see can be answered, organize a group of five or six people and prepare a report for the class, using either your group's data or data from the whole class. Which do you suppose would give you the most meaningful answers — data from one person, the group or from the class? Would it have been a better idea to let one person grow twenty-five level four Kr rye seeds and compare his results with someone else's twenty-five level eight Kr seeds?

From time to time you will find short writings based on research going on at the University of Oregon Medical School and Portland State College or Oregon State University. Often there will be questions to answer along with the article. You should do them in writing unless otherwise instructed. The first of this series regards a small bacteria which is highly resistant to radiation.

## XIV.4.1 - INVISIBLE SHIELD AGAINST ATOMIC RAYS

A small, white nouse in the microbiology laboratory is exposed to a big dose of radiation -- enough to kill him; in fact, more than enough to kill a man.

The mouse is put back in his cage, and Dr. A. W. Anderson, bacteriologist, and his assistants at OSU await the first signs of damage -- lack of energy, dull eyes, rough fur -- that show up in less than two weeks when blood cells are dying and no new ones are being formed.

This little mouse, however, stays alert. He scampers about his cage and up the wire sides. He eats well, his eyes remain bright, his coat smooth.

Shortly before his radiation exposure, he had been given a hypodermic injection of a compound taken from a round, red, microscopic bacteria discovered at OSU. This strange bacteria is fantastically resistant, even to as many as 5 or 6 million roentgens of atomic radiation.

The mouse is one of many injected in laboratory experiments with substance from the bacteria, and is one of the approximate 50% injected that apparently will survive exposure to powerful radiation.

Research at OSU on radiation resistance in inoculated mice is comparatively new, and results are far from complete. The work has received a generous grant from the National Institutes of Health. Although it sounds like science fiction, the ultimate object is to find a substance to inject into human beings to increase their radiation resistance. Such resistance could be valuable to persons working with radio-active materials and, in time of possible war, could mean the protection of millions of people.

Why some of the mice seem to be resistant while others are not is not yet understood. Frequent blood tests show that the ability to form white blood cells in all exposed mice is destroyed;

but in some -- about half -- the damage is not permanent; soon white cells reappear and function normally.

The bacteria itself was discovered by accident at OSU by Dr. Anderson and his associates.

Dr. Robert F. Cain, food technologist, was doing research on irradiation methods of food preservation. Various foods were sealed fresh in cans or in cellophane packages and then exposed to various amounts of radiation. In most cases all food damaging bacteria inside were killed with relatively low exposures and the food stayed perfectly preserved until the seal was broken. However, in some batches of canned irradiated beef, some of the cans began to swell, indicating that all damaging bacteria had not been killed.

Microbiologists found a bacteria never before isolated. In further experiments the bacteria, recently named _Micrococcus radiodurans_, was exposed to radiation so powerful its container turned black. But when the bacteria were put back on a culture, they busily went on living and reproducing.

Micrococcus radiodurans looks like a number of other roundish cells except that it grows in a clump of four. Photographs, taken by electron microscope and enlarged up to 100,000 times, show that the clump has tissuelike cell membrane between the bacteria. Researchers elsewhere are now investigating other aspects of this bacteria, including its mechanics of radiation resistance.

New equipment at OSU, a Cobalt 60 Irradiation Source, to be used in further food irradiation studies, also will be used in studies of Micrococcus radiodurans. Microbiologists at OSU will be able to investigate respiration and other functions of the bacteria during radiation exposure.

### XIV.4.2 - GENES AND POPULATIONS

Read sections 17-6 to 17-8, Blue text.

### XIV.4.3 - POPULATIONS IN TRANSITION

Read sections 17-9 to 17-12, Blue text.

### XIV.4.3a - Experiment: EFFECT OF POPULATION SIZE -- A STUDY OF HUMAN EVOLUTION

(Ex. 17-3 Green)

### XIV.4.3b - Investigation: THE SNOW GOOSE

One of the great questions which has plagued the evolutionist is the seemingly sudden disappearance or appearance of large populations of given species of organisms. These changes seem to be faster than the early evolutionist believed possible. There is a model of this kind of shift in the population which we in Oregon may be able to watch in the coming ten to forty years. This involves the populations of snow geese which winter in Oregon. The change has been going on in other parts of the continent for many years and is just beginning to show signs of occurring here, too.

For further details you should consult the reference Dr. J. P. Linduska, "Blue Goose: the Enigma of the North," Sports Afield, 157 (May, 1967).

The first evidence cited concerns some hunters who remarked about the drop in the number of snow geese they were getting in their bags at a certain resort. The operator confirmed their observation and set them on the track of some data about the decline in the snow goose population. Through the reports of various agencies of water fowl management, they pieced together some striking field observations.

In 1941 the breeding flock at Eskimo Point (west coast of Hudson Bay) was estimated at 14,000, six of which were blue geese, a color phase of the snow goose. This is something akin to a herd of 14,000 white horses with six brown horses in it. There is little question of the accuracy of the original count.

The flock had grown in size rather steadily to a count of 25,000 in 1961. The number of blue geese now, however, was 6,000.

There are other large breeding flocks which have shown remarkable increases in the per cent of the population that is in the blue phase. Someday all the snow geese may be of that color. Estimates suggest that if the present rate continues, that change will take place in the Mississippi flyway flocks by 1975. Some breeding flocks are now 97% blue and 3% white. There are no records of when the first blue geese were reported in those particular flocks; they may have been present for hundreds of years.

Currently in Oregon there are infrequent reports of a blue goose or two on Sauvies Island. Thus, the genes which produce this color difference have been introduced into the gene pool of the breeding flocks that winter here. A good observer will be able to document the interaction between the normal and abnormal color phases of the population here.

From this data a working hypothesis could be formulated according to the concept of natural selection: if the blue population is able to survive so well in competition with the typical snow goose, there must be something about the blue trait which makes survival more likely. Many scientists have been observing this development in an attempt to gather data to support or reject this hypothesis.

Here are some of their observations. Label them "plus" if they help the blue goose take over, "minus" if they hinder it, or "✓" if they are neutral.

If you have no basis for an answer, then use a "zero" to indicate that you are unable to interpret the observation. If you think the statement is very important one way or the other to the blue geese, you might choose to use the notations "++" or "--". It may be that you will want to write in a brief statement of why you interpret the observation a certain way. You should at least be prepared to discuss your pattern of reasoning. You may need to revise early answers in the light of later statements.

____(1) Geese tend to mate for life and often refuse to take a new mate if they are separated.

____(2) The young geese tend to stay with their parents for 2-3 years until they are mature.

____(3) The geese from a given breeding ground tend to return to it year after year; they rarely show up in some other area.

____(4) Generally the breeding grounds are many miles apart and the surplus bachelors or spinsters cannot find mates from neighboring populations.

____(5) The climate of northern Canada where they breed, is in a warming trend. The habitats are undergoing physical change.

____(6) White snow goose females show no reluctance to accept blue goose males as mates.

____(7) White snow goose males show no sexual interest in blue females at all. In an unusual situation six white male snow geese had a chance to select any of three blue females and not one courtship was initiated.

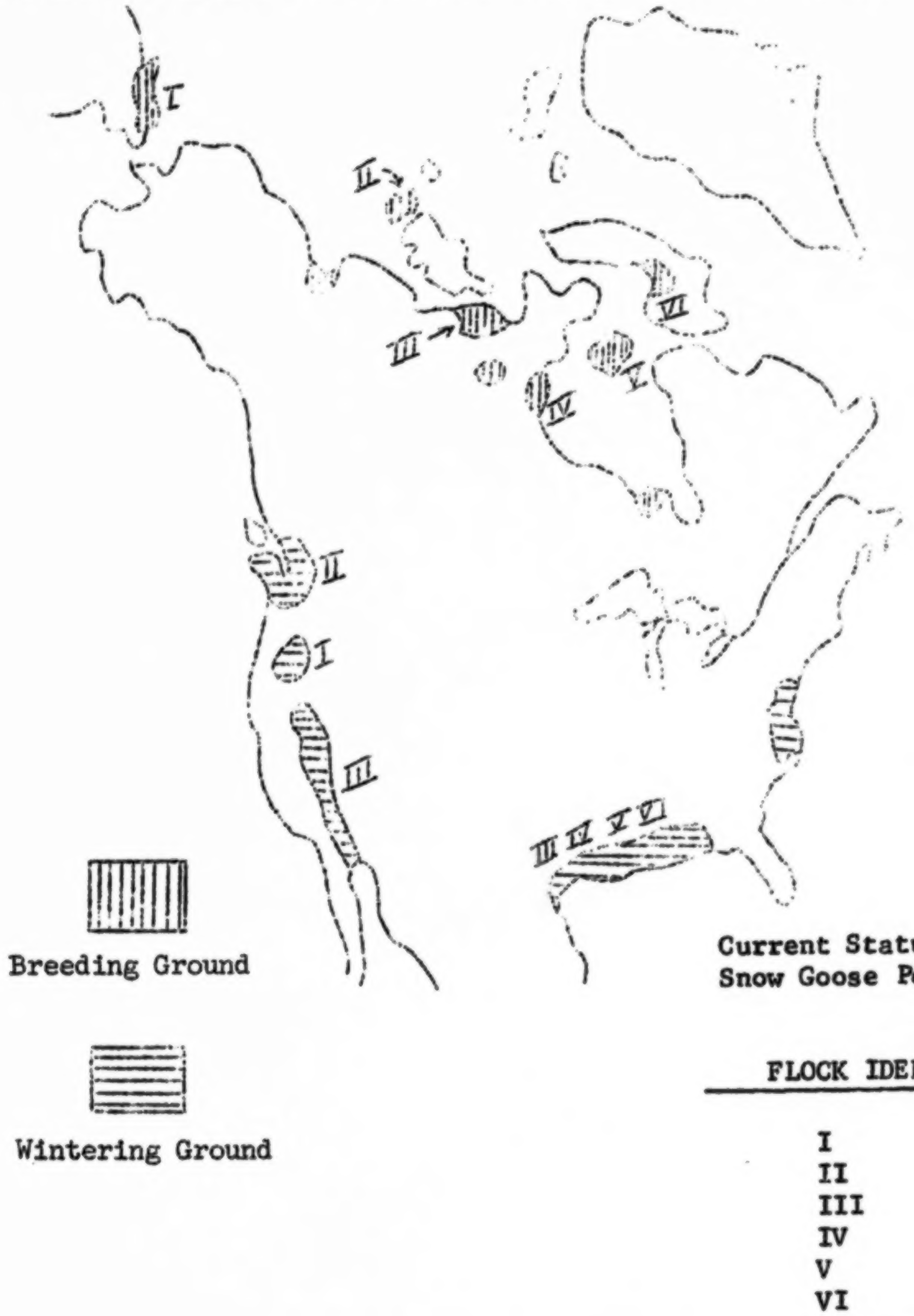
____(8) White snow geese tend to nest early. In a breeding flock all the eggs laid on the first and second day of the season were laid by white snow goose pairs. Not one of the one-day or two-day eggs survived long enough to hatch. They were eaten by jaegers (carnivorous birds, not precisely predators) or flooded out.

____(9) The eggs in a clutch that will hatch into white snow geese have a greater chance of being the last to hatch. They are laid later or simply take three or four days longer to incubate than the blue goose-producing eggs.

____(10) In an experiment one hundred of each kind of goose were banded. That season hunters returned thirty-three white snow goose bands and twenty-one blue geese bands.

____(11) In a wintering flock (juveniles tend to stay with their parents 2-3 years), 33% of the white snow geese and 12% of the blue geese were orphans. In a preserve flock of similar type there was no significant difference between the per cent of orphans in the white snow and blue geese.

FIG. XIV.3 - Lesser Snow Goose Wintering and Breeding Grounds


I
II
III
IV
V
VI
II
I
III
III IV V VI
Breeding Ground
Wintering Ground

**Current Status of Blue Phase Snow Goose Populations**

| FLOCK IDENTITY | PERCENT OF FLOCK BLUE PHASE |
|---|---|
| I | 0 |
| II | Trace |
| III | 10 |
| IV | 15 |
| V | 30-40* |
| VI | 50-99 |

*Each breeding ground serves several flocks which have various percentages of Blue Phase Lesser Snow Geese.

## XIV.4.4 - THE ORIGIN OF NEW TYPES

Read sections 17-13 to 17-16, Blue text.

### XIV.4.4a - Investigation: DEVELOPMENT OF A NEW BREED OF LABORATORY DOG

"New Canine Breed Claims Distinguished Ancestors," from Imprint, (University of Oregon Medical School, Winter, 1967).

The decision to try to develop a new breed stemmed from the need for a medium-sized standard laboratory dog for use in organ transplantation, shock studies and gastric physiology. Small animals have been inbred and studied until it is now possible to obtain healthy uniform animals of known age, weight, sex, genetic background and characteristics. But investigators requiring larger animals are forced to use pound dogs of completely unknown genetic background, age and health.

Several colonies of purebred dogs have been developed throughout the country for use in specific projects. These include the Beagles for radiological research and drug testing, and a number of other breeds for nutritional, developmental and behavioral studies. Despite this, no well conceived long term project to develop a larger laboratory dog has been undertaken.

The Oregon team's first step was to decide which traits such a dog should have. They came up with these specific characteristics: genetic uniformity, large litters, early maturity, stress resistance, 35-40 pound size, easy to care for, gentleness, trainability, shorthair and light skin (for dermatology studies), short or curly tail (grooming and cage cleanliness), quietness and cage tolerance.

First they studied various existing breeds to see if any met these established criteria. Rogers, a native New Englander, was interested in the Fox Hound but found they were almost nonexistent on the Pacific Coast.

The animal care team found that the Bull Terrier, or Pit Bull as it is often called, has many characteristics they were looking for--short hair, weight about 50 pounds, broad chest and a relatively short tail. But the disposition of the breed worried the researchers. Historically the Bull Terrier was bred as a fighting dog and the team felt they could run into problems if they housed more than one dog to a run.

When their search failed to turn up an ideal dog among existing breeds they began choosing the purebred stock to use in developing a new breed.

They found the Labrador Retriever had more of the desired traits than any other of the readily available breeds. The Labs originally came from the West Coast of New Foundland where they were prized as fearless water dogs and retrievers as early as the beginning of the 19th century. This was a good trait for Oregon's damp climate.

Selected specimens of the breed had been taken by trading vessels to

England where most of them were bought by wealthy persons to breed and use as retrievers. Standards were set and the breed carefully improved by vigorous culling. As a result almost all pedigreed Labradors can be traced to a very few well-known dogs.

The Lab is the only breed which cannot be made a bench champion without at least a working certificate in the field. This means they must retrieve ducks and pheasants under fire. As a consequence, they have never been bred indiscriminately for conformation without regard to strength, endurance, temperament, intelligence and trainability. The outcome of these partly fortuitous and partly far-sighted occurrences is that many of the best specimens of the Labrador have very high coefficients of inbreeding and yet have not lost the admirable qualities for which they are well-known.

At about the same time the Lab was chosen as the base breed in the

Oregon program, a prominent Portland woman whose hobby was breeding top Labs decided to close her kennel. The Medical Research Foundation of Oregon purchased these dogs for the Medical School. "This was fortunate" Rogers said, "we were able to start our colony with some of the country's finest stock."

While generally quiet the Lab is not "barkless," nor does it have a short or curly tail. In an attempt to obtain these traits the "barkless," curly tailed African Basenji was chosen to cross with the Labs. Actually the Basenji is not mute but it seldom barks, and its vocalization comes out more like a chortle or yodel.

The Basenji is a true historic breed, there being pictorial evidence that the dogs were known in Egypt five thousand years ago and have changed very little since that time. On engraving in tombs dating 3600 B.C. the Basenji is shown as a house dog, attached to the chair of the master. From the time of ancient Egypt until the middle of the 19th century, Basenjis faded into obsecurity, although evidence shows that deep in Central Africa, away from civilization, they were valued and preserved. Then, around 1870 explorers returning from the Dark Continent spoke about these unusual dogs.

The first Basenjis are reported to have been brought into the United States about 1937 and the breed was given American Kennel Club recognition in 1943.

Unlike most male dogs, the Basenji is capable of breeding only during a short period each year, usually from September to December. Rogers' team hopes to overcome this drawback by establishing a frozen sperm bank for artificial insemination.

The results of these Lab-Basenji breedings were encouraging to the UOMS team. Most of the pups had some curl in their tails and tended to bark much less than the purebred Lab pups.

Next, to retain size, further develop the curly tail and broad chest, and try for lighter skin, another historic breed was introduced into the line--the Samoyed.

Since the Lab is a relatively new breed, Rogers' group felt it was important to use ancient breeds with a background of hundreds of years of pure breeding and consistent genetic background for the remainder of the breeding stock.

The Samoyed gets his name from the partly nomadic Samoyed tribes of northwest Siberia. For centuries the Samoyed has been the faithful servant of his primitive owners. Sled dog, guard dog, shepherd of reindeer, the Samoyed is energetic and tireless. He is capable of pulling one and a half times his weight even under the most difficult conditions of weather and terrain.

The fourth and final breed chosen was the Greyhound, another of the breeds that has an authentic history of over

5,000 years. This dog has long been associated with royalty. Under the laws of Canute, King of England and Denmark in the eleventh century, no person below the rank of Gentleman was permitted to own a Greyhound. Its popularity in many countries for thousands of years is apparent by the numerous carvings, statues, paintings, and tapestries showing him in the company of kings, nobles and huntsmen.

Its short, smooth, firm-textured coat, its stamina and its weight of around 65 pounds favored its inclusion in the program. But more important for a research breed, the Greyhound has very large blood vessels.

At the time the program was started the team felt it would take at least six generations to determine if the plan would work. But the project has developed faster than expected with each generation showing more and more of the desired characteristics. Now, with fifth generation offspring bounding around the kennels at the School's 180-acre farm the researchers can predict success. In another four generations (about six years) they expect the new type of dog to breed relatively true.

Detailed records are kept on each dog in the breeding colony, including when the bitches' oestrous cycles occur, how long they last, and the number of puppies per litter. Nutritional, environmental and genetic background is maintained on all dogs.

Records on puppies born in the colony rival those pediatricians keep on babies. Pups are weighed once a week for the first 12 weeks, then once each month until they reach maturity. To establish a base line blood tests are done on each pup every three months.

When the pups are eight weeks old they undergo a series of weekly tests, which were designed by Guide Dogs For the Blind. These tests include such tasks as fetching, sitting on command, following moving objects, coming when called as well as the measurement of their response to noise, to being put on a wire-mesh floor, to having their ears and toes gently pinched and their tails petted. Results of these tests, showing which of the pups are most intelligent, best tempered and most sensitive, assist the animal care team in planning future matings.

Because a dog's future reaction to humans is determined by its experiences at three to 12 weeks of age, all personnel at the farm are encouraged to handle and play with the young pups as much as possible--a chore that takes little urging.

At six and nine months the young dogs are graded according to the established standard of desired characteristics. Rogers is encouraged with over-all results to date. Dogs of the newly developing breed bark very little, their tails are beginning to curl, their hair is short, the skin

-

fairly light and socialization with humans is good.

The public relations aspect of such a dog breeding program was demonstrated recently when one of the nation's leading dog clubs, the Ventura County (California) Dog Fanciers Association, sent Rogers a check in support of the program. Association President Jim Henderson said,

> "The importance of dog-breeding programs to dog lovers lies in the fact that the faster animal research colonies around the country become self sustaining, the less will be the schools' need to depend on dog dealers or to buy pound animals. Those men who steal dogs to sell to unknowing research institutions will be forced out of business, because there will no longer be any market for their animals."

Commenting on the gift Rogers said, "To my knowledge this is the first time such a group has done this. This is most encouraging to us in the field who are vitally concerned with providing healthy animals for medical research and giving these animals the finest care possible."

## XIV.5 - THE HUMAN SPECIES

### XIV.5.1 - THE RISE OF MODERN MAN

Read sections 18-1 to 18-4, Blue text.

### XIV.5.2 - THE GENES OF MAN

Read sections 18-5 to 18-8, Blue text.

### XIV.5.2a - Experiment: SICKLE CELLS AND EVOLUTION

(Ex. 17-4 Green)

### XIV.5.2b - Investigation: GENETICS OF SOME HUMAN TRAITS

How can you determine the genetic pattern of some particular traits in your family? A useful tool in studying human genetics is the technique of making family pedigrees. A simple checking of your family and relatives will reveal inheritance patterns in a number of the following:

## Comparing lengths of ring and index fingers

Place the first three fingers of your hand on a flat surface with all three fingers straight and held together. Note that a straight line drawn as a tangent to the tip of the ring finger passes behind the tip of the middle finger. Index finger lengths vary from significantly shorter than the ring finger to longer than the ring finger.

## The occurrence of mid-digital hair

The fingers consist of three segments -- terminal, middle and proximal. An inspection of the middle segment of each finger may reveal hairs present on some and absent on others. The most frequent combination consists of hair on the ring finger only. The next most common situation involves hair on ring and middle fingers. Hair appears less frequently on the ring, middle and little fingers. Least commonly, hair appears on the middle segments of all four fingers.

## Hyperextensibility of the thumb joint

Some individuals possess the ability to flex the basal joint of the thumb so as to make nearly a 90° angle between the 2nd and 3rd segments of the thumb.

## Preference of pattern of interlacing fingers when folding the hands

When you are asked to fold your hands, you will find there is a tendency to fold them the same way each time. Some fold their hands so that the left thumb overlaps the right thumb. Others fold their hands so that the right thumb overlaps the left thumb. Folding your hands in a manner opposite to the normal tendency usually gives an awkward or peculiar sensation.

## Preference of pattern of folding the arms

When asked to fold your arms, as in folding your hands, there is a tendency to fold them in the same manner each time. Some individuals fold the right arm over the left. Others fold the left arm over the right. Folding the arms in the opposite way is found to be awkward if not difficult.

### Shape and manner of attachment of the ear lobes

The lobe of the ear differs in shape from one individual to another. The difference is due in part to the manner of its attachment. Some lobes are pedant, being attached at a point above the bottom of the ear lobe. Another interesting trait involving ear shape is Darwin's Point, a lump of cartilage occurring on the edge of the curl of the ear. Sometimes it occurs on one ear, sometimes on both.

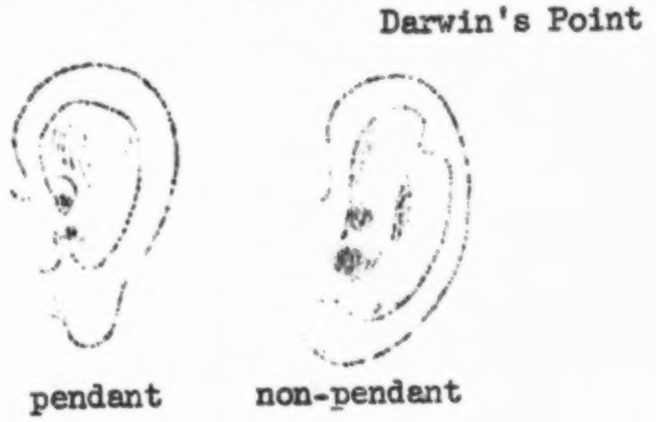


FIG. XIV.4

### Widow's peak

The shape of the hairline across the forehead varies from individual to individual. Some persons exhibit a dip of the hairline at the middle of the forehead to form a point, other's do not.

## Tongue musculature and control

By rolling the sides of the tongue up and in, certain individuals possess the ability to roll the tongue into a hollow cylinder. Very rarely, an individual is found who can form a clover-leaf pattern with the tongue by rolling the edges and the tip. Some individuals can fold their tongue tip so as to touch it to the back of their tongue. Others are able neither to curl nor to fold their tongue.

## Master or dominant eye

Though usually unaware of it, we tend to favor the use of one eye over the other. To demonstrate this, hold a pencil at arms length with both eyes open. Direct the pencil at a small object across the room and look along it. Without moving the pencil, close the left eye. Now try the right eye. When you close your dominant eye, the pencil appears to hop. Though the other eye may be used as readily for this sighting, your master or dominant eye is the eye you tend to favor unconsciously.

## Taste traits

The ability to taste certain chemical substances is determined genetically. Three commonly available substances which are detected variously by different individuals are listed below.

(1) Phenylthiocarbamide (PTC) or phenylthiourea (PTU) -- 7 out of 10 persons will detect a definite taste. Others will taste nothing. Most persons sense a bitterness.

(2) Thiocarbamide or thiourea -- the same type or response will be sensed as with PTC. Some persons, however, will taste one and not the other.

(3) Sodium benzoate--this substance may taste salty, sweet, bitter or may not taste at all. The taste response to this chemical combined

with that to PTC has an interesting relation to distastes for certain foods.

Chart a family pedigree of any three of the above using a form similar to the one used in lab. 17.4 of your Green lab manual or in section 16-7 of your Blue text.

### XIV.5.3 - THE GENETICS OF HUMAN POPULATIONS

Read sections 18-9 to 18-14, Blue text.

### XIV.5.3a - Experiment: A STUDY OF POPULATION GENETICS

(Ex. 17.2 Green)

### XIV.5.4 - CHANGES IN HUMAN POPULATIONS

Read sections 18-5 to 18-18, Blue text.

### XIV.5.4a - Experiment: BIOLOGICAL DISTANCE

(Ex. 19.3 Green)

# - Chapter XV: Reproduction -

## XV.1 - ESSENTIAL FEATURES OF REPRODUCTION

Review sections 13-1 to 13-4, Blue text.

## XV.2 - SEXUAL REPRODUCTION IN PROTISTS AND PLANTS

Read sections 13-5 to 13-11, Blue text.

### XV.2a - Experiment: REPRODUCTION IN PARAMECIA

The survival of any group of organisms, plant, animal or protist, is dependent upon the ability of individuals of that group to give rise to more of their own kind--to reproduce. This process of reproduction may be a rather direct phenomenon involving only a single parent that divides, fragments or produces extensions that drop off, thus producing two or more individuals. This is called asexual reproduction. Many species, however, exhibit sexual reproduction in which case two specialized cells, each called a gamete, fuse in a process called fertilization to produce a combined cell, the zygote. The zygote, the first cell of the new individual, obviously will contain contributions from both parents and thus be different genetically from either parent.

Some organisms are capable of reproducing both sexually and asexually. Such an organism is a paramecium, a small one-celled, slipper-shaped protist which commonly lives in pond water. Did you observe this organism when studying the different kinds of living things found in pond water?

Paramecia reproduce asexually by means of a process specifically called fission. This phenomenon can perhaps best be studied by observing a prepared slide of paramecia made from a population which was reproducing rapidly. Observe such a slide under the microscope. Locate a specimen which appears constricted in the middle. It is dividing into two organisms. Make an outline sketch of the entire protist. Paramecia are rather unique in that the nuclear material is segregated into a kidney-shaped macronucleus and one or more small spherical micronuclei rather than contained in just one typical single nucleus. Examine the specimen under high power. How does the shape of the nucleus in a dividing organism compare with that of a paramecium not undergoing fission? Add the nuclear structures to your sketch. What is happening to the nuclear material?

Examine the slide under low power and look for several stages of fission. Make a series of drawings showing your understanding of the sequence of events from the onset of fission until the two organisms appear held together by a very narrow bridge of cytoplasm. What is the over-all result of this constricting process?

Which organism is the "parent"? What similarity do you see between cell division and this type of reproduction? Why is fission considered to be "asexual reproduction"?

Paramecia also reproduce sexually by means of a process called conjugation. Study this process by observing live specimens. For their size, paramecia are rapid swimmers and, unless slowed down somewhat, are difficult to study alive under the microscope. A thick, syrupy substance called methyl cellulose may be used to restrict their rapid movement. Make a ring of methyl cellulose solution about 5 mm in diameter in the middle of a clean microslide. Place a drop of paramecium culture in the middle of this ring, place a cover slip in position and observe under the microscope.

Locate two paramecia which appear to be stuck together side by side. These organisms are undergoing conjugation. Watch the organisms for a time. Make an outline sketch of the two.

A few drops of iodine stain placed at one edge of the cover slip and drawn under by means of a small piece of paper toweling applied to the opposite edge, will kill the paramecia and stain them so that the nuclei of each cell become visible. Compare the appearance of the nuclei with those of paramecia on the slide which are not undergoing conjugation. How do the nuclei differ? Is the condition of the nuclei similar to that observed in paramecia undergoing fission? From your observations can you form any hypotheses about what is occurring between the two paramecia undergoing conjugation? Following this process of nuclear exchange, the two organisms will separate and each member will immediately undergo cell division.

Although partners undergoing conjugation are structurally identical, it has been found that they belong to different mating types. This means that a paramecium of mating type I will conjugate with an individual of mating type II and vice versa. Thus, while structurally the same, functionally the two partners are different and therefore somewhat analogous to male and female.

Do you think fission or conjugation would be the most advantageous type of reproduction for continuing the species under changing environmental conditions? Why? Under what conditions do you think fission might be the most advantageous type of reproduction?

### XV.2b - Investigation: REPRODUCTION IN FLOWERING PLANTS

(Invest. 30 Blue)

## XV.3 - SEXUAL REPRODUCTION IN ANIMALS

Read sections 13-12 to 13-17, Blue text.

### XV.3a - Experiment: SEA URCHIN REPRODUCTION

Following the production and release of eggs and sperms, the next step in sexual reproduction is fertilization during which two gametes combine to form a zygote. If all goes well, you will be able to observe this fascinating and dynamic process under the microscope.

Before the laboratory period, your instructor should have obtained freshly released eggs and sperms from live female and male sea urchins. The gamets are kept in cold sea water approximating their natural environment as closely as possible.

Obtain a clean microslide and using a clean pipette, place on it a drop of the egg suspension. Close to the side of the drop of eggs, _but not touching it_, place a drop of the sperm suspension using a different pipette. (Why should you use different pipettes transferring the two suspensions?) Carefully observe a sea urchin egg. Note its size, shape and color. Can you detect any details within the egg? Now look carefully at the drop of sperm. Watch their movements. What is their shape, color, size? Compare the egg and sperm in regard to these structural characteristics. Can you suggest any advantage in producing gametes of two different morphological sorts? For what are sperms particularly adapted? How is the egg especially suited for its role in reproduction?

Now, while looking through the microscope, use a toothpick to draw part of the sperm suspension over to the drop of eggs. Mix them together and watch. You should see a rare and fascinating sight. Make a note of the time when you first mixed the gamets.

What response do the sperms exhibit with respect to the eggs? Very soon after the penetration of an egg by a sperm, a fertilization membrane lifts off from its surface and surrounds the egg like a halo. How long did it take from the first contact of sperm with an egg for this fertilization membrane to form? Can you suggest a function for the fertilization membrane?

Within an hour or so, the fertilized egg, or zygote, will start to divide into two cells as the new individual begins to develop into an embryo. Shortly each of these cells will divide again to form four. These produce eight, and so on. If the zygotes are kept in fresh, cool sea water in a shallow dish, such as a Syracuse watch glass placed in a refrigerator, you should be able to observe development of these stages over a period of hours and days.

In many animals, testes and ovaries are located in the same individual. Give several examples. Can you suggest any advantages to this arrangement? Can you suggest disadvantages? How could these disadvantages be reproduced?

## XV.4 - REPRODUCTION IN PLACENTAL MAMMALS

Read section 13-18 to 13-23,

Blue text.

## XV.4a - Experiment: A MOUSE COLONY FOR THE HIGH SCHOOL LABORATORY

## XV.5 - HORMONE CONTROLS OF THE REPRODUCTIVE SYSTEM IN MAMMALS

Read sections 13-24 to 13-27,

Blue text.

# - Chapter XVI: Development -

## XV.1 PROBLEMS OF DEVELOPMENT

Read sections 14-1 to 14-6, Blue text.

## XVI.1a - Experiment: CHICK EMBRYO DEVELOPMENT

After an egg has been fertilized by a sperm, what events must occur before that egg may become an independent organism at birth or hatching? In the next three week period you will be making direct observations of a living chicken embryo to study these events as they occur.

Normally, many eggs must be incubated and the contents of the egg removed each day if an observation is desired. With a simple modification, you can be looking into the same egg day after day, watching a continual and progressive development occurring in the embryo. This requires the placing of a 2 cm hole in the shell of the egg. Observation of the developing chick will be made through this opening. Keep in mind that what you see in 3 weeks is very similar in many respects to the thirty-six weeks of events which led up to your birth.

A large number of these opened eggs will die during the 21 days of development because of (a) inability to turn the egg from day to day which may lead to deformities and (b) contamination through the egg opening by bacteria and fungi which may lead to disease and death. However, certain techniques and precautions, when carefully followed, will give better results.

A plexiglass ring or copper pipe can be used as an egg holder. This should be about 3 cm in diameter and about 3 cm in height.

Sterilization of all equipment used cannot be overemphasized. A primary cause of embryo death before complete development is the lack of antiseptic precautions. Instruments should be flamed, the laboratory table sterilized with alcohol or covered with paper toweling, hands carefully washed, and the eggs lightly washed with cotton dabbed in alcohol.

Windows should be placed in the chick eggs after 72 to 96 hours of incubation.

Eggs are placed in the ring holders with the pointed end down. A hole, about 2 cm in diameter, is made in the blunt end of the egg by lightly cracking the egg with forceps and removing the shell. Care should be taken not to rupture any blood vessels in removing the shell and outer and inner membrances. If a better field of vision is desired, albumen may be removed with a sterile pipette.

A sterile 150 ml beaker should immediately be placed over the egg and egg holder. Avoid excessive breathing on the eggs. All observations should be made through the beaker.

The egg, egg holder and beaker should then be placed in the incubator by carrying the beaker over the egg when transporting to the incubator. Not all of the eggs placed in the incubator can be expected to reach full mautrity and hatch. Those that die should be removed since the exposed yolk and embryo make excellent media for bacteria and fungi growth.

Observations should not be made randomly; they will prove more useful to you if you follow a time schedule and record your findings. Students may, on occasion, remove the eggs from the incubator for short periods of time (2-3 minutes). A stereodissecting scope is desirable for detailed study. However, the beaker must remain over the egg and egg holder at all times. Heart beat, chick movements and gradual appearance of internal and external organs will take on new meaning. Observations can now be made at any time; you will find out what is occurring between the more traditional daily or weekly opening of an egg. With this apparatus you can make a continual observation of the same living chick embryo as it develops.

A log of observations (from which you will be asked to draw conclusions on growth and development in three weeks) should be kept daily and include detailed labeled drawings, measurements, heart beat counts and written observations. A suggested chart for your observations is given below.

| Age of Chick Embryo | Written Observations | Detailed Labeled Drawings |
|---|---|---|
| | | |

Read carefully Exercise 15.3 in your Green lab book which will give you ideas for your observations as will Chapter 14 in your Blue textbook. Your librarian will furnish still more materials.

Should the embryo you are observing die, indicate this in your observations, then continue your observations on another student's embryo. This will alter your observations only slightly since all embryos should be within about 24 hours of being the same age.

After the chicks have hatched, you will be asked to write a summary of observations and conclusions to explain what has occurred. You should include in this summary answers to the questions that follow.

Ask your teacher about other experiments which can be done using the living chick embryo. You may want to design your own.

Exercises for Home, Desk and Lab (HDL)

(1) Why did the heart seem to appear very early in development while other organs did not appear until much later ?

(2) Did the rate of heart beat increase or decrease during development? Why?

(3) How does the chick embryo get its oxygen supply?

(4) What happens to solid and gaseous wastes during development.

(5) How many chambers has the heart at five days? At ten days? At birth?

(6) Develop a rationale for the order in which organs seemed to appear.

(7) Why did the eye, an organ not used until after birth, appear so early?

(8) What parts of the developing egg never become part of the chick and how do they serve a purpose in the chick's development?

(9) Is the rate of growth constant during development?

(10) Graph the rate of growth and the rate of heart beat.

(11) What other observations can you or can't you explain?

(12) Briefly explain how this chick embryo's development compares to a human embryo's development.

## XVI.2 - EVENTS OF DEVELOPMENT

Read sections 14-7 to 14-11, Blue text.

## XVI.2a - Experiment: DEVELOPMENT OF AN EMBRYO: FROG

(Ex. 15.5 Green)

## XVI.2b - **Experiment:** ANIMAL STRUCTURE AND FUNCTION: THE FROG

(Ex. 14.1 Green)

## XVI.3 - EXPLANATIONS OF DEVELOPMENT

Read sections 14-12 to 14-16,

Blue text.

## XVI.4 - UNUSUAL KINDS OF DEVELOPMENT

Read sections 14-17 to 14-20, Blue text.

### XVI.4a - Experiment: VEGETATIVE REPRODUCTION: REGENERATION (ANIMAL)

(Ex. 15.1 Green)

## XVI.5 - REGULATION IN PLANTS

Read sections 24-1 to 24-3, Blue text.

### XVI.5a - Experiment: PLANTS ON A PHONOGRAPH

If young plants were placed on a phonograph and spun at about fifty revolutions per minute, which way would they grow? How do you explain and support your answers?

As a demonstration your teacher has set up such an experiment. Observe this carefully for the next week. What has happened? After discussing factors of plant growth and after reading your text assignment, explain what has happened. Pull up the plant carefully. What has happened to the roots? Why?

In no case does a stem or root "like" a particular environment. Plant reactions and growth can be explained in terms of certain growth laws which your teacher will explain. These laws must be applied to answer such questions as (1) why do stems grow up; (2) why do roots grow down; (3) why will a plant placed on its side turn up; (4) why do stems grow towards a strong light source.

XVI.5b - Experiment: TROPISMS

(Ex. 18.3 Green)

XVI.5c - Investigation: PATTERNS OF GROWTH IN PLANTS

(Invest. 33 Blue)

XVI.5d - Investigation: REGULATION OF GROWTH IN PLANTS

(Invest. 51 Blue)

XVI.5e - Investigation: GROWTH CURVES

(Invest. 32 Blue)

# Chapter XVII: The Integrated Organism And Behavior

## XVII.1 - THE BIOLOGY OF BEHAVIOR

Read sections 27-1 to 27-3, Blue text.

### XVII.1a - Experiment: UNUSUAL PLANT BEHAVIOR

When the topic of behavior or responses to environmental stimuli is mentioned, most people think of animals. These are the kinds of organisms which very obviously, quickly and often dramatically respond to stimuli and indeed exhibit intricate behavior patterns. Yet it is true that plants respond, too. Most plant responses are growth responses or tropisms, as they are called, but there are some plants which are capable of movement and will behave in specific ways. This movement is usually slow. For example, some plants always have their flowers pointing towards the sun, following the sun through the sky during the day. Many clover species fold their leaves like a fan at dusk.

A few plants, however, exhibit responses which appear much more "animal-like" in nature. Among these is the sensitive plant, or Mimosa pudica, as it is called by scientists.

You should work in groups of four for this exercise. Obtain a potted sensitive plant and place it on the laboratory bench. Do this very carefully so that the plant is not touched, jarred or shaken even by wind currents. If the leaves fold up, you have been too rough and your experiment is in jeopardy.

Have one member of your team record the data obtained from observation of the reaction of the plant to various types and strengths of stimuli. First, take a dissecting needle and gently touch one of the near-terminal leaflets. Wait a few seconds. Record any reactions. Touch the leaflet again somewhat more firmly. Again record any reaction. Be careful not to jiggle the whole plant. If any of the leaflets of the leaf you touched have not folded, again brush the leaflets.

Take a glass rod approximately 20-30 cm in length and heat one end in a flame. Bring the heated end close to (but not touching) a leaflet which has not yet been stimulated. Record results. Observe a sensitive plant which has been placed in a refrigerator for at least one hour and record the state of leaf position.

Obtain an electric stimulator and adjust it to deliver a series of electrical discharges of about 1 volt. Very, very carefully, in order to avoid touch stimulation, place the electrodes against a near-terminal leaflet of a non-stimulated leaf. Hold the electrodes steady for a few seconds to see if the plant has received tactile stimulation. If it has not, have one team member close the switch and deliver electrical stimulation for 3 seconds. Wait 5 seconds and record any reaction. If none occurred, double the intensity of electrical stimulation and repeat. Continue doubling the intensity until a strong reaction occurs. Record results at each voltage.

What do you conclude as to the variety and kinds of stimuli effective on a sensitive plant?

Can you suggest any possible adaptive or selective value this folding reaction might have for the plant?

Compare the responses of the sensitive plant with what you think would happen if you stimulated an earthworm similarly.

What structures and body systems would be involved in an earthworm's reactions? Do plants have such organs? Can you suggest how this plant is capable of reacting the way it does?

Could you devise an experiment that would test your hypothesis?

### XVII.1b - Experiment: PHOTOPERIODIC CONTROL OF PLANT BEHAVIOR (Ex. 18.2 Green)

### XVII.1c - Experiment: SOME CHARACTERISTICS OF LIVING MATTER (Ex. 12.5 Green)

### XVII.1d - Experiment: EFFECTS OF SALINITY ON LIVING ORGANISMS (Ex. 9.3 Green)

## XVII.2 - ANIMAL BEHAVIOR

Read sections 27-4 to 27-9, Blue text.

### XVII.2a - Experiment: A HEART AT WORK (Ex. 14.3 Green)

Many individual responses in terms of adjustment to the environment are made without conscious awareness of the factors triggering the change. Your rate of inhalation and exhalation has already changed many times today, but you are just becoming aware of the fact that you are breathing as you read this. When you start to think about breathing, changes may occur which are not automatic. Breathing for a while may require conscious effort. Why is it a good thing that you can control this process or not as you choose? Exercise 14.3 Green is about an automatic response to the environment in daphnia.

### XVII.2b - Experiment: RESPONSES OF SOW BUGS

Sow bugs are crustaceans. They are one of the few branches of the family tree which now live on land. Like other crustaceans, they are gill breathers and require a fairly high level of moisture in the environment (air) to survive.

In a large pan or enamel tray place a piece of paper towel which is moist. In some other part of the pan or tray, place a piece of paper towel which is not moist. The pieces should be some distance apart. Place the sow bugs allotted to you between the pieces of towel and at approximately 30-second intervals record the number of sow bugs on the tray, the dry towel and the wet towel.

Can the sow bugs find water? Must they touch it to know it is there?

Set up a large tray with a desk lamp over it. Place the allotted sow bugs in the center of the tray and map their movements over the surface of the tray.

Describe their placement on the tray at the end of 3 minutes. (Are they randomly distributed, bunched, or other?)

Place one transparent and one opaque shelter (each 2" x 2" x $\frac{1}{2}$") in the tray. Put the sow bugs on the tray between the two shelters and record their positions as in the earlier phase of this experiment.

Can the sow bugs detect light? What is their response to light? How would you proceed to find out which wavelengths of light the sow bugs can see and which ones they cannot?

Discuss an experiment to test for responses to temperature. Do you think that temperature was an uncontrolled factor in the part of the experiment that tested their light responses? Explain. Describe the habitat you would expect sow bugs to favor.

Do you think that it is possible to condition sow bugs to do something they would not normally do? The following exercise will give you an opportunity to find out.

Construct a T-maze as shown in FIG. XVII.1 or FIG. XVII.2 to find the natural direction a given sow bug turns. (A spot made by a felt-tip pen will individualize the sow bug.) Start the sow bug up the stem of the T. When it reaches the end of the stem, it will turn. Record the direction in which it turned. After twenty to thirty trials you will have a pretty good idea of its natural turning direction.

Light and handling are rough on sow bugs. It is recommended that they be "worked" on the following basis: 5 minutes of rest between runs, no more than ten runs per day. Your team ought to be able to observe care in their treatment and still expedite the experiment by using at least four sow bugs at a time.

After determining the natural pattern of turning, attempt to condition the bug to turn the opposite direction. Let the sow bug run up the stem of the T. You should be aware by this time that sow bugs do not stay very long where it is dry, hot or light. Therefore, if it turns the natural way, confine the sow bug in this arm and shine a bright light on it from a distance of 4-5 cm for 10 to 15 seconds. When the sow bug turns the desired way, do not punish it. (Remember the rules: 5 minutes to cool off and no more than ten runs a day.)

When the sow bug makes the "unnatural" turn nine times out of ten, it is conditioned as thoroughly as it ever will be. Do not punish the sow bug any more and see how long it takes to forget all that it has learned.

In selecting the sow bugs to use, it is important to choose those which seem to be strongly left- or right-handed. Ambidextrous sow bugs will guarantee failure of this experiment.

You have tried punishment as an inducement to learn. Can you devise a scheme to reward the sow bug for correct reactions rather than punishing it for incorrect ones? Should you use the previously conditioned animals for this experiment? What is the effect of the past experiences they have had? Keep in mind that the reward or punishment comes after selection of the arm. Be careful not to lure it into the "right" choice.

Would you consider it possible to use a T-maze to find out if mice can see certain colors or to find out if beetles are as "smart" as sow bugs?

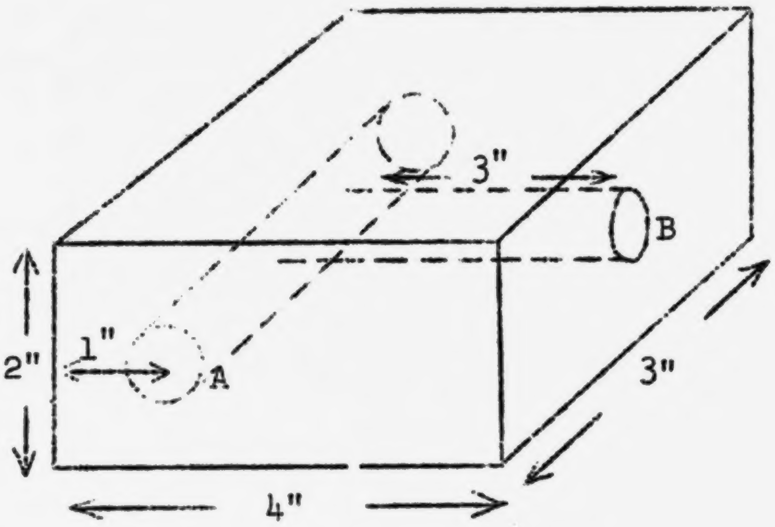


FIG. XVII.1 Wood T-Maze

## T-Maze Construction

Wood Shop Version:

Block of wood, 2" x 3" x 4"

Drill two ½"-diameter holes into the block. "A" goes all the way through (arms of T); "B" intersects "A" (stem of T). Then cut into two t-blocks on band saw (see ceramic version).

Ceramic Version:

Block of clay, 1" x 3" x 4" with gouged grooves. Fire and glaze.

Both versions are topped with clear, fairly stiff plastic. A fluffy cotton swab makes a good plunger for closing the arms.

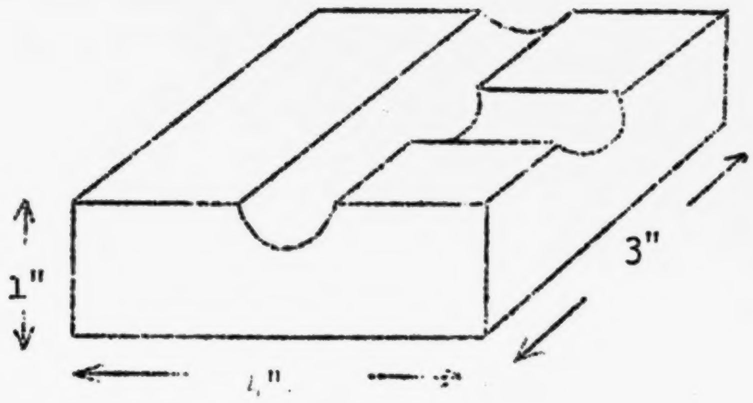


FIG. XVII.2 Ceramic T-Maze

## - Chapter XVIII: Populations -

### XVIII.1 - THE POPULATION CONCEPT

Read sections 28-1 to 28-5, Blue text.

### XVIII.1a - Experiment: SPACE VERSUS POPULATION IN DROSOPHILA

Your teacher has set up a demonstration for you to observe. You will record the effects of crowding upon an animal population.

### XVIII.1b - Experiment: POPULATION GROWTH: A MODEL (Ex. 2.1 Green)

### XVIII.1c - Experiment: A STUDY OF A YEAST POPULATION (Ex. 2.2 Green)

### XVIII.1d - Experiment: FACTORS LIMITING POPULATIONS (Ex. 2.3 Green)

### XVIII.1e - Experiment: HUMAN POPULATIONS

Populations are never static. One would hardly expect the number of people in Portland to be the same today as it was twenty years ago or as it will be twenty years from now. The population of this classroom changes from hour to hour and from day to day. But by observing past populations, we can often make reasonable predictions about the future.

To illustrate, look at the data provided and attempt to visualize what the numbers mean. It seems reasonable that the data will need some work to make them understandable.

## Population Growth of the United States

| Year | Projections | Population |
|---|---|---|
| | | Note A |
| 1960 | | 181,000,000 |
| 1965 | | 198,000,000 |
| 1970 | | 219,000,000 |
| 1975 | | 243,000,000 |
| 1980 | | 272,000,000 |
| | | Note B |
| 1960 | | 180,000,000 |
| 1965 | | 195,000,000 |
| 1970 | | 213,000,000 |
| 1975 | | 235,000,000 |
| 1980 | | 245,000,000 |
| | | Note C |
| 1960 | | 179,000,000 |
| 1965 | | 191,000,000 |
| 1970 | | 202,000,000 |
| 1975 | | 225,000,000 |
| 1980 | | 245,000,000 |
| | | Note D |
| 1960 | | 179,000,000 |
| 1965 | | 193,000,000 |
| 1970 | | 202,000,000 |
| 1975 | | 215,000,000 |
| 1980 | | 230,000,000 |

Note A: Projection assumes that fertility will average 10% above the 1955-57 level for the whole projection period 1958-80.

Note B: Projection assumes that fertility will remain constant at the 1955-57 level for the whole projection period 1950-80.

Note C: Projection assumes that fertility will decline from the 1955-57 level to the 1949-51 level by 1965-70, then remain at this level to 1980.

Note D: Projection assumes that fertility will decline from the 1955-57 level to the 1942-44 level by 1965-70, then remain at this level to 1980.

## Estimates of World Population (in millions) by Regions, 1650-1957

| Date | Africa | Asia (exc. U.S.S.R.) | Europe and Asiatic U.S.S.R. | Oceania | World Total |
|---|---|---|---|---|---|
| 1650 | 100 | 257 | 103 | 2 | 470 |
| 1750 | 100 | 437 | 144 | 2 | 694 |
| 1850 | 100 | 656 | 274 | 2 | 1,091 |
| 1900 | 141 | 857 | 432 | 6 | 1,571 |
| 1920 | 140 | 967 | 486 | 8.8 | 1,810 |
| 1930 | 155 | 1,070 | 531 | 10.4 | 2,031 |
| 1940 | 170 | 1,213 | 572 | 11.3 | 2,246 |
| 1950 | 199 | 1,376 | 575 | 13.2 | 2,493 |
| 1957 | 225 | 1,556 | 618 | 15.4 | 2,797 |

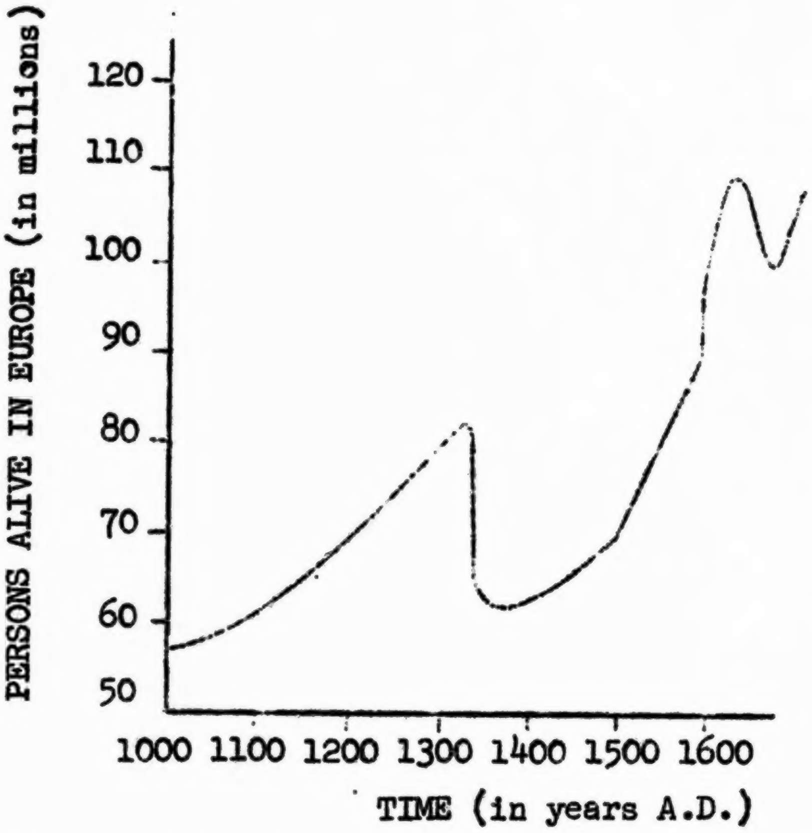
A simple time versus population graph will make the data clearer.

Your teacher will help you decide how to attack the battery of data presented so that you can get a better idea what is happening to the population of man. He will ask you to do some projecting yourself about the future population of man.

Do you understand graphing? Study the following graph on European populations.

Has the grapher used techniques which would tend to confuse or mislead? If you think so, list as many as you find.

Write a word interpretation of the graph.



## XVIII.2 - SOME POPULATION PROBLEMS

Read sections 28-6 to 28-8, Blue text.

## XVIII.2a - Investigation: THE EFFECT OF CROWDING ON POPULATIONS

The state of Oregon keeps track of campground use in terms of camper nights. Here are a few appropriate figures:

| | |
|---|---|
| 1960 | 595,023 |
| 1961 | 708,210 |
| 1962 | 842,408 |
| 1963 | 877,658 |
| 1964 | 1,003,881 |
| 1965 | 1,127,928 |
| 1966 | 1,307,121 |

How long has it taken us to double the use of park camping facilities? How long will it take to redouble the use?

Some experts project that at present human population growth rate, every square foot of land surface will be covered by people in six-hundred years. It has been suggested that the only way to house this fantastic population would be to have 2,000-story buildings.

However, experience has shown that populations do not grow and grow to infinity. Rather, an equilibrium is ultimately reached where the number of individuals entering a population is balanced by the number leaving. What measures may stabilize the human population? Regardless of the frightening prospects of future population levels, we have a problem today -- hunger. Most nations of the world are pressed for food. We will not have to wait for the year 2000 to see people starving; world famine is predicted by 1975.

Some experts have called hunger the second hydrogen bomb. Starvation today takes a high annual toll of lives on a world-wide basis.

Even if adequate food is available, another problem still faces man that is the problem of crowding. Some hints that the problem is imminent are now becoming available through the study of other animal populations.

In an American Institute of Biological Sciences meeting at the University of Colorado, Stephen H. Vessey presented a significant paper. He wrote of the social-physiological mechanisms which were discovered working in animal populations.

Vessey found that crowding in mouse populations results in an increase in the size of the adrenal cortex (a pale yellowish gland on the upper end of each kidney which secretes several important hormones). These hormones interfere with antibodies, the substances in blood that fight infection and disease. It seems obvious that if resistance to infection decreases as a population increases, crowding directly increases morbidity (disease and death) in populations.

In an experiment to test this idea, Vessey injected mice with beef serum, a substance that normally stimulates the production of antibodies in animals. The mice were then tested for the antibodies present in the bloodstream. The mice living in groups were found to have fewer antibodies than mice living alone.

In other experiments, mice were given tetanus toxoid shots. Tetanus toxoid is the protein or antigen that stimulates production of antibodies against tetanus. Ten days later the mice were injected with tetanus toxin (the disease-producing agent). Some of the mice had been living in groups. Others had been isolated in jars for controls.

"After the toxin was injected, 33 of the 40 grouped mice died," Vessey said. "Only 11 of 30 isolated mice died -- from tetanus."

Some social factors in mice have also been studied. Dominant individuals in a group had more antibodies than other mice in the same group.

It was further discovered that mice exposed to an aggressive mouse suffered higher mortality from tetanus toxin after toxoid than did mice exposed to a non-aggressive mouse. Thirteen of 19 toxoid-toxin injected mice died when exposed to an aggressive mouse. Five out of 25 mice died when exposed to a non-aggressive mouse.

Prior to 1949, it was believed that the chief agents for regulating populations were food supply, climatic factors, disease and war. Now that many of these factors are being controlled, more or less, many scientists are turning to internal mechanisms as possible controlling factors of populations.

In the December 18, 1964, issue of Science, an article on endocrines, behavior and population proposed the hypothesis that a behavioral-physiological mechanism operates to control population in mammals.

Results of work with mice, rabbits, muskrats, deer and other mammals yield supporting evidence that endocrine feedback mechanisms exist in mammals. These internal mechanisms can regulate and limit population growth in response to increases in "social pressure".

Listed are some of the physiological responses to increases of populations, particularly in mice. These resulted from over-activity or underactivity of endocrine glands.

(1) Reproductive functions lessened in both sexes.

(2) Sexual maturation was delayed or, at high population densities, totally inhibited.

(3) Weights of sex organs declined.

(4) The female's egg cycle was extended (more time between releases of eggs).

(5) Death of fetuses in the uterus increased.

(6) Inadequate lactation (milk secretion) in mice; nurslings were stunted.

(7) Crowding of female mice prior to pregnancy resulted in permanent behavioral disturbances. Future pregnancies were decreased.

(8) Increase of certain hormones permanently affected the development of the brain in mice.

(9) Negative sex responses, believed to result from lack of gonadotrophin secretion that stimulates the sex glands, occurred.

The researchers noted also that in increased populations there was an increased susceptibility to infection or parasitism. This may well have resulted, from a decline in the formation of antibodies. Some investigators therefore believe epidemics occur in crowded populations because resistance is lowered. From this point of view disease is a result of high population as well as a cause of a decline in population.

It has been suggested that if physical factors such as disease, climate, and food do not regulate a population, then behavioral-endocrine mechanisms take over. Thus, a population is prevented from becoming so dense that the environment is destroyed; eventual extinction of the animal ensues.

Much of the work with mammal populations has been done under control conditions in the laboratory. This is one reason why some scientists will not accept the data as meaningful. They feel that more work on internal mechanisms in mammals must be done in the field where the animals may react to overcrowding in other ways.

The big question is, can we interpret the data obtained from mice, rats, rabbits and deer as applying to humans. These new areas of research on overcrowding complicate matters. The population explosion, then, is not just a problem of food and space shortage. More research is needed to learn the mental, social and physiological effects overcrowding produces in humans as well as in other animals.

## XVIII.2b - Experiment: PARAMECIUM COMPETITION

Your teacher has prepared a supply of water and food for you to use in this experiment. Each team will need three very clean baby food jars (cleaned with hot water, soap and scrubbing plus rinsing several times in very hot water) Place 25 cc of water with four grains of wheat into each jar. Label them "A", "B", "C" ("A" -- Paramecium aurelia:

"B" -- both P. aurelia and P. caudatum; and "C" P. caudatum). Also include some identification of your group on each jar.

In a few days the teacher will provide you with appropriate inoculations of P. aurelia and P. caudatum. Mix the water in the jar thoroughly. Use a small drop of the water (after inoculation) as a sample. Search for paramecia in the drop. Record the number of paramecia of each species in each drop. Samples should be drawn daily for two weeks.

| Date | Jar A | Jar B | | Jar C |
|---|---|---|---|---|
| | Pa | Pa | Pc | Pc |

Use the data to make two graphs. Place jar "A" and "C" on one graph and jar "B" on the other. Does competing with P. aurelia affect the growth curve of P. caudatum? Does the reverse hold true?

## - Chapter XIX: Societies -

### XIX.1 - THE STRUCTURE OF SOCIETIES

Read sections 29-1 to 29-4,

Blue text.

### XIX.2 SOCIAL ADAPTATIONS

Read sections 29-5 to 29-9,

Blue text.

## - Chapter XX: Communities -

### XX.1 - THE STRUCTURE OF COMMUNITIES

Read sections 30-1 to 30-5, Blue text.

### XX.1a - Experiment: LIMITING FACTORS IN DISTRIBUTION (Ex. 8.1 Green)

## XX.1b - Experiment: LAYERING IN A HAY INFUSION

You have been observing the hay infusion for some time, gathering data for the study of succession in XX.2g. Do not stir up the infusion today. Take your first sample drop from the middle of the jar and from the shallowest depth you can (right at the surface). Count the various kinds of organisms and record the number of each kind observed. Next, take a sample drop from the middle of the jar and again count and record kinds and number of organisms. Then remove a small drop from the surface of the substrate (if there is no accumulation of material at the bottom of the jar, then consider the bottom of the jar as the substrate). Again record kinds and number. Use small, uniform drops. Bear in mind that if the drops vary in volume, counting ten organisms in one sample may equal counting twenty organisms in another. If you have ample time, try samples from other describable regions within your jar.

Does the environment vary enough within the jar to make very special habitats? Are there organisms which are able to survive throughout the jar? Are there some organisms which are so specialized that they are only found in one habitat within the jar? Cite some factors which bear on your answer to the previous question.

Why was it necessary to stir up the infusion when taking samples for observation of succession?

XX.2 - THE FUNCTIONS OF A COMMUNITY

Read sections 30-6 to 30-10, Blue text.

XX.2a - Investigation: TRACING A FOOD CHAIN (Invest. 60 Blue)

XX.2b - Investigation: TRANSPORT OF PHOSPHATE IN PLANTS (Invest. 61 Blue)

## XX.2c - Investigation: SEWAGE PLANT FOOD WEB

Few people consider what happens to the garbage going down the drain of a kitchen sink or the waste flushed from a toilet. Yet one of the most profound and beneficial food webs and energy exchanges takes place soon after those household acts. Pollution, while a major problem today, is minimized to a

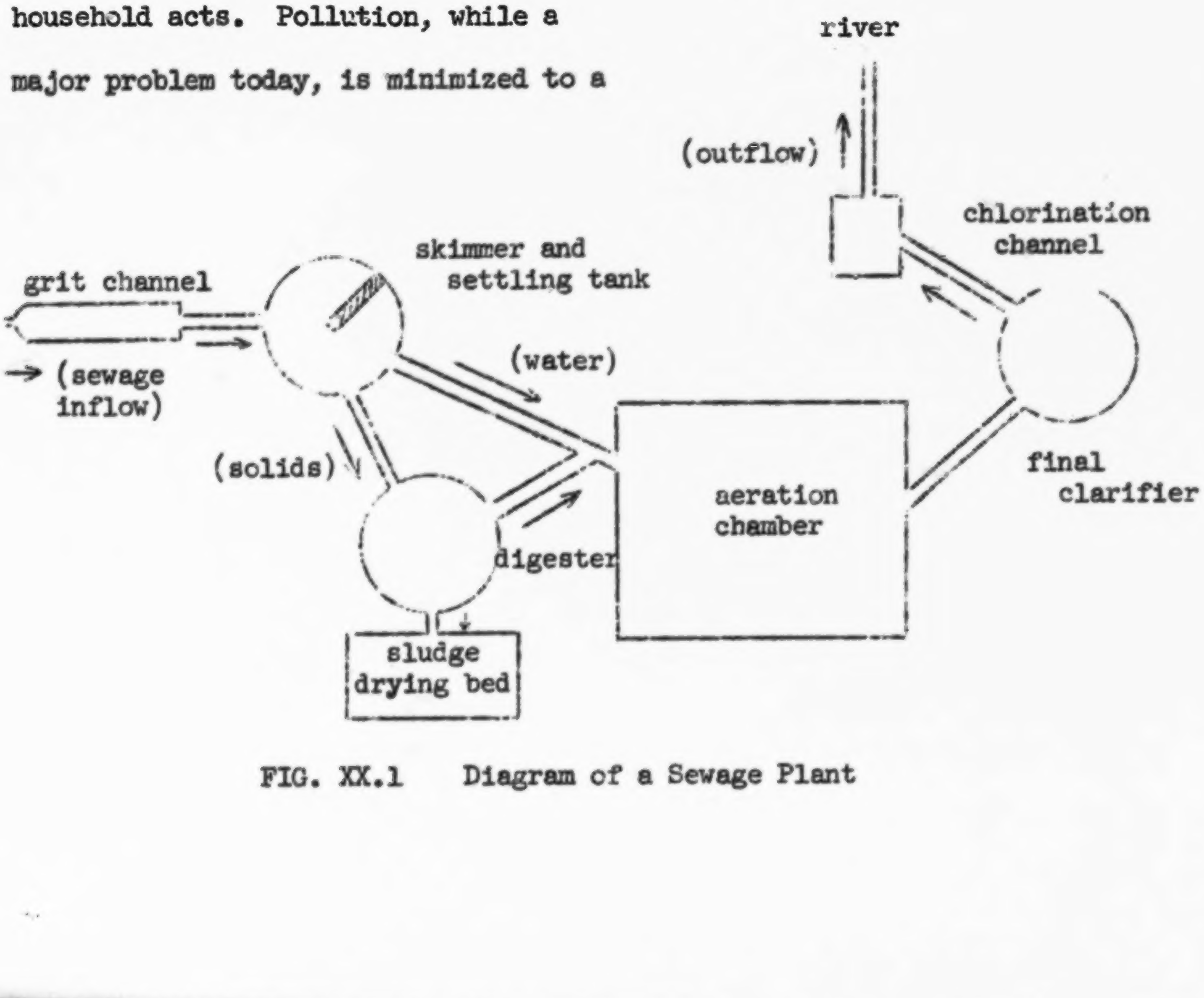

river
(outflow)
chlorination channel
grit channel
skimmer and settling tank
(sewage inflow)
(water)
(solids)
final clarifier
aeration chamber
digester
sludge drying bed

FIG. XX.1 Diagram of a Sewage Plant

major degree by the bacterial action of sewage plants.

A major change takes place in human wastes and other garbage which enters a sewage treatment plant--that is the change of solid wastes to gases before the water is dumped into one of our rivers. It is this change that reduces pollution of the rivers by these kinds of wastes.

Before discussing the bacterial food webs that cause this change, study FIG. XX.1.

Incoming sewage is passed through a screen and grit channel where large objects such as floating wood and heavy objects such as rings, watches, rocks and tin cans are removed and hauled to a junk yard. Sewage then passes to the skimmer and settling tank where water speed is greatly reduced, allowing sewage either to settle to the bottom or to float on top. Last year in Washington, D.C., money from a bank robbery was found one morning floating in this tank, apparently flushed down a toilet or stuffed into a storm sewer by the robber. Much of the human waste and garbage is removed from the bottom at this point and this solid material (now called sludge) is transported to a huge tank, the digester.

It is in the digester that beneficial bacteria perform the basic function of the sewage plant. Anaerobic bacteria (those requiring no oxygen for respiration) feed on the sludge and produce water and gases in the process:

$$\text{sludge} \xrightarrow{\text{anaerobic bacteria}} \text{methane} + \text{carbon dioxide} + \text{water}$$

Enough methane gas is produced at the Portland, Oregon, sewage plant by bacteria to heat 1500 homes per year. However, this gas is used only within the sewage plant to heat the digesters to a temperature range of 95° to 100° F and to heat the maintenance buildings at the plant. The excess gas is burned off and released to the air. In other words, much of the incoming sewage has been released as gas into the air by the work of the sludge-digesting bacteria. Why are the digesters heated to 95°-100° F temperature? It is interesting to note that an auto was once constructed in England which used sewage and garbage in a miniature digester to produce methane gas for fuel.

Some sludge is indigestable by the bacteria and is therefore removed to a sludge drying bed. This sludge has a high mineral content and, after drying, may be used as fertilizer only on crops which will be cooked. Why only non-raw crops?

One plant which consistently sprouts in this sludge area is the tomato plant. These seeds are quite resistant to the bacterial actions of the sewage plant. Those which go down the drain of a home may well be found at a later date sprouting in a sludge drying bed.

Not all sludge settles in the settling tank. In fact, as much remains suspended in the water as settles. This, too, must be removed. Water with the suspended wastes is moved to the aeration chamber where the water is vigorously churned to add as much oxygen as possible to the water. Here the aerobic bacteria feed on the suspended wastes in the process:

$$\text{sludge} + \text{oxygen} \xrightarrow{\text{aerobic bacteria}} \text{carbon dioxide} + \text{methane} + \text{water}$$

Water is then moved to a final clarifier tank where these bacteria settle out and are returned to the aeration chambers. Before water is dumped into a river, it is chlorinated to kill any remaining bacteria, especially the pathogens causing such diseases as typhoid fever and tetanus which are prevalent in sewage plants.

### XX.2d - Investigation: ISLE ROYALE STUDY

Situated some 15 miles off the Canadian coastline in Lake Superior is a natural laboratory which is now the scene of a ten-year investigation being carried on by Purdue University with the support of the National Science Foundation. Durward Allen and David Mech have written a non-technical account of the first few years of the study in National Geographic (February 1963). It is recommended that you look into the article for details and excellent photographic coverage of the synopsis here presented.

Isle Royale is about 45 miles long and ranges between 3 and 7 miles in width. It has many bays, spits and lakes which make it a popular area for people to play during the summer. The serious work of the study is carried on during about seven weeks each winter when the gray wolf, Canis lupus, hunts in packs. Much of the basic observation is done from airplanes, allowing the relatively small research staff to keep track of what is going on in their 210-square-mile "test tube." Use of the airplane has permitted them to observe the pattern of behavior of the pack in 136 stalks and four kills of the

American moose, Alces americana, by Canis lupus.

The investigators feel that their work has great biological significance because this island has just about the last remaining population of the gray wolf in the United States. Prior to this study, the record of animal migrations to and from the island has been incomplete. It takes some hunting and a lot of guessing to piece together a picture of the animal history of the island.

Ever since the island was formed, there have probably been snowshoe hares, red squirrels, mink, weasels and muskrats among the ordinary animal complement. It seems reasonable to predict that they will continue to be common residents in the foreseeable future. With the larger mammals, the picture is not so consistent.

At the turn of the century, caribou, lynx and martin were reported on the island. None of these has been seen there since 1926. At that time foxes, coyotes and beaver first appeared in the fur traders' records. Foxes and beaver are still around, but the last report of a coyote track was in 1957. It is deduced that the first moose crossed over to Isle Royale on the ice in the winter of 1912.

A biologist on foot made an estimate of the moose population in 1929. He reported between 1000 and 3000 moose. At 25 pounds of browse (shrubs, etc.) per day per adult moose, it is small wonder that the biologist suggested drastic control measures be taken to protect the population. Nothing was done.

In 1936 a forest fire retarded the population explosion. In the reestablishment of the typical Lake Superior-type forest, a brushy shrub stage is common. This provides yet today even more food than the moose found on the island in 1912. One might, therefore, be surprised to find that in 1963 an air-count of the midwinter moose population was 529 with an estimate of 600 as the probable total population of moose on the island. Why hasn't the population exploded? The big difference is wolves.

First observed in 1949, the wolf population now stands at twenty-one or twenty-two. In the four years of observation only one wolf pup has been raised. The moose population should produce at least 225 calves per year.

During the summer few people see the wolves. However, sightings of adult moose escaping from a wolf or two by wading into the lake, suggest that moose calves (and beaver) are the chief summer diet for the wolves.

A wolf in the winter needs a lot of meat and bone. A cow moose that weighed about 800 pounds (100 pounds of waste) fed sixteen wolves for three days. They then ate sparingly for a few days until another kill was made. Male wolves weighing between 80 and 100 pounds are larger than females.

A bull moose, if killed, would provide about twice as much food as a cow. There is a recorded observation of a healthy cow standing off at least fourteen wolves for the better part of a day. The pack then isolated a feeble cow and took the relatively easy meal in a few hours. It seems unlikely that very many prime bulls are ever attacked.

Sixty-eight kills have been examined. Often only blood stains and hair remained in a churned-up patch of snow. Sometimes, however, there was enough evidence to gauge the health of the moose.

Of the moose killed, the most common age was nine to ten years old. Calves less than one year old were the second most common group killed. No moose at all between one to five years of age were killed.

Forty-five per cent of the adult kills examined had some health as well as an old age problem. The kills included eleven which had lumpy jaw (a form of cancer) and fourteen which had little or no fat in the bone marrow (anemic). All had numerous tapeworm cysts in their lungs.

This island now shows all the earmarks of a community in balance in terms of large mammals. However, with its past record, Isle Royale may soon be providing a different problem for scientific study in the midst of Lake Superior.

## Exercises for Home, Desk and Lab (HDL)

(1) How much moose meat does a wolf need each day to survive in the winter? (Try to work in terms of maximum consumption and recognize that your answers must be estimates.)

(2) How much meat do the wolves need each day to survive in the winter?

(3) How many moose did the wolves eat during the one hundred days of winter? (Assume 800 lbs. is the largest size moose killed.)

(4) How large a herd does it take to keep this number of moose available for winter wolf food?

(5) How many pounds of plants does a moose eat in a year?

(6) How many pounds of plants does the moose population eat in a year?

(7) How many pounds of plants would the moose population of 1929 have consumed?

(8) Compare the number of pounds of browse consumed by moose, the number of pounds of moose and the number of pounds of wolves in the community supported on Isle Royale.

(9) What was the density of the moose population in 1929 (moose/sq. mile)?

(10) What was the density of the wolf population in 1929 (wolves/sq. mile)?

(11) What was the density of the moose population in 1963 (moose/sq. mile)?

(12) What was the density of the wolf population in 1963 (wolves/sq. mile)?

## XX.2e - Experiment: SYMBIOTIC RELATIONSHIP BETWEEN TERMITES AND FLAGELLATES

It is easy to show that termites have intestinal residents, mostly flagellate protists, but not so easy to show their interaction to be mutualistic. Termites are not born with these residents; they are infected with them by their comrades. They also lose them in the molting process, thus requiring reinfection. This demonstrates the mutual need of one organism for the other. There are many wood-eating organisms with intestinal residents of the same general type (e.g., cattle, wood-boring beetles, etc.).

Grasp a termite's abdomen between your index finger and thumb. Squeeze gently. A brown discharge usually has flagellates in it. Recently molted termites may show a clear or white discharge which is free of flagellates.

Squeeze the anal discharge onto a microslide and add a drop of 0.2% NaCl to make a wet mount. Mount the discharge with an eye lash or hair which will support the cover glass and keep it from crushing the many species of flagellates that should be present.

### XX.2f - Experiment: EFFECTS OF FIRE ON BIOMES (Ex. 8.3 Green)

Some kinds of organisms are so highly adapted to a particular set of circumstances that they are severely limited by their environment. Such an organism is Kirkland's warbler which has had a nearly stable population of about one thousand for many years. This bird, a resident of Michigan, requires a jack pine forest of young trees (eight to twenty years old or 6 to 18 feet tall). Kirkland's warblers are not found in stands of jack pine less than 80 acres. Furthermore, for nesting reasons the soil must drain quickly. The birds nest on the gound and will only build where the lower branches of the pines have enough sunshine to be kept alive and in full needle. The branches must touch the ground or low shrubs. In this part of the world, forest fires are becoming rarer. The jack pine, therefore, lives longer and presents the warblers with a problem--that is, finding suitable nesting sites. One might predict that the warbler would eventually become extinct.

But man has done something about it. A 17-square-mile sanctuary is expressly maintained for Kirkland's warblers and the other members of the community. The sanctuary has a program of clearing and planting jack pine which insures the proper nesting sites for this very rare bird. The U.S. Forest Service is experimenting with the use of controlled forest fires to help manage the problem, too.

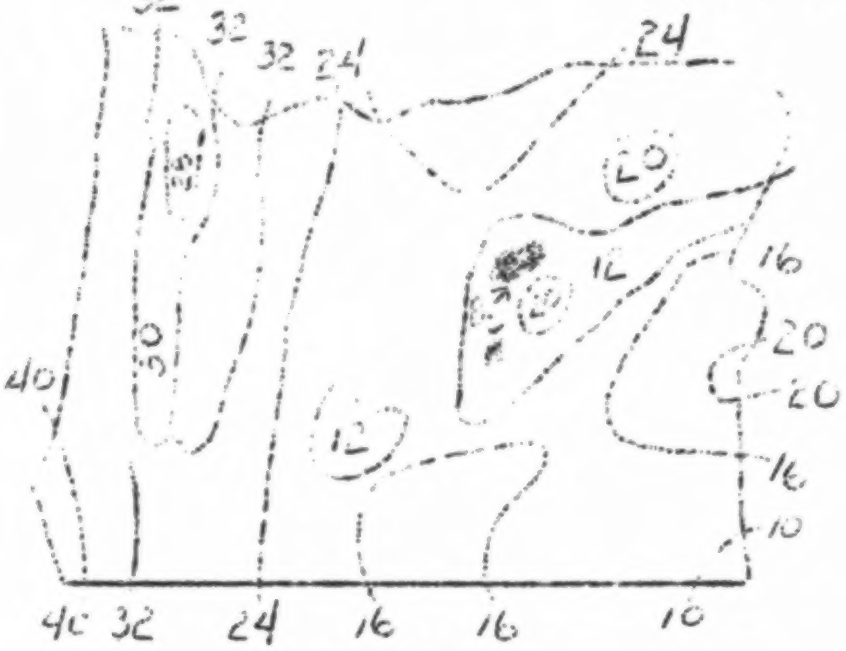
## XX.2g - Experiment: SUCCESSION IN FRESHWATER COMMUNITIES: A LABORATORY STUDY (Ex. 9.2 Green)

## XX.2h - Investigation: BIOGEOGRAPHY OF OREGON

There are other physical factors of the environment besides fire which affect the distribution of plants and animals. Climate, the average weather conditions prevailing in an area, is certainly one of the major factors operating on any community.

The maps that follow divide Oregon into various regions depending upon several distinct features of the weather. Organize the information on the maps into one map showing the climatic regions of Oregon. It is generally recognized that there are seven or eight main climatic regions in the state.

FIG. XX.1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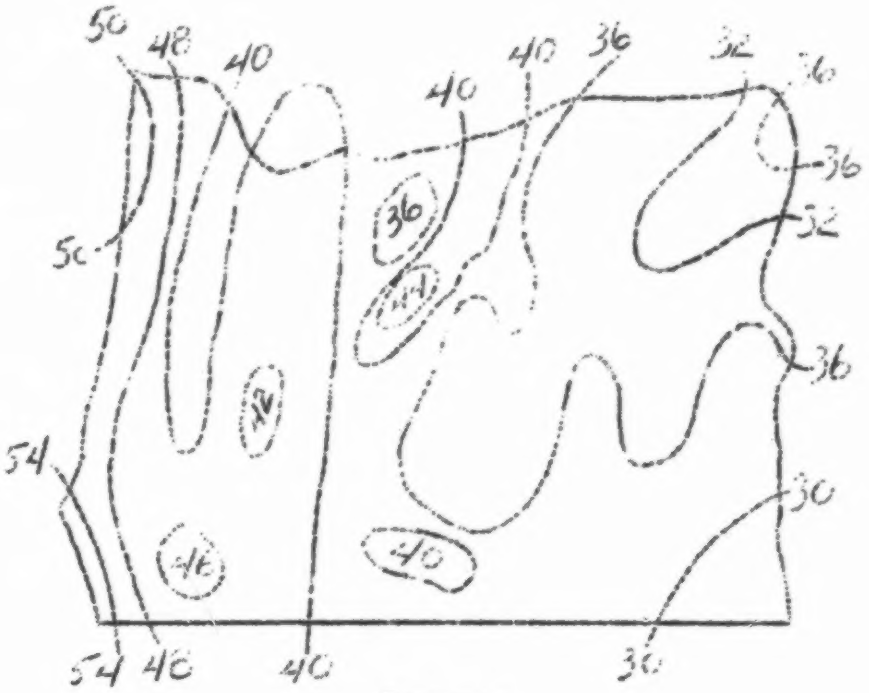
10

January
A - Average Low Temperatures (°F)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48
40
40
40
36
32
36
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44
42
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46
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54
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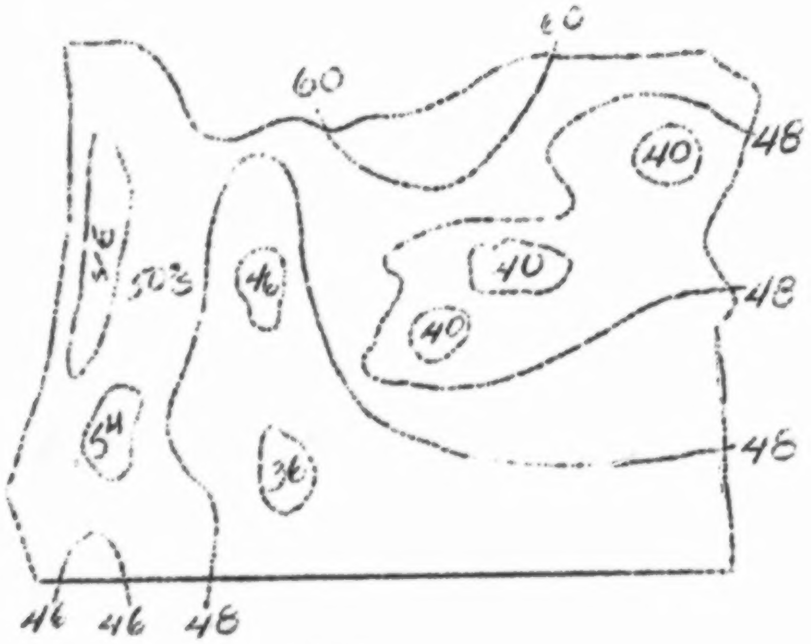
40
30

January
B - Average High Temperatures (°F)


60
60
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40
48
46
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50°3
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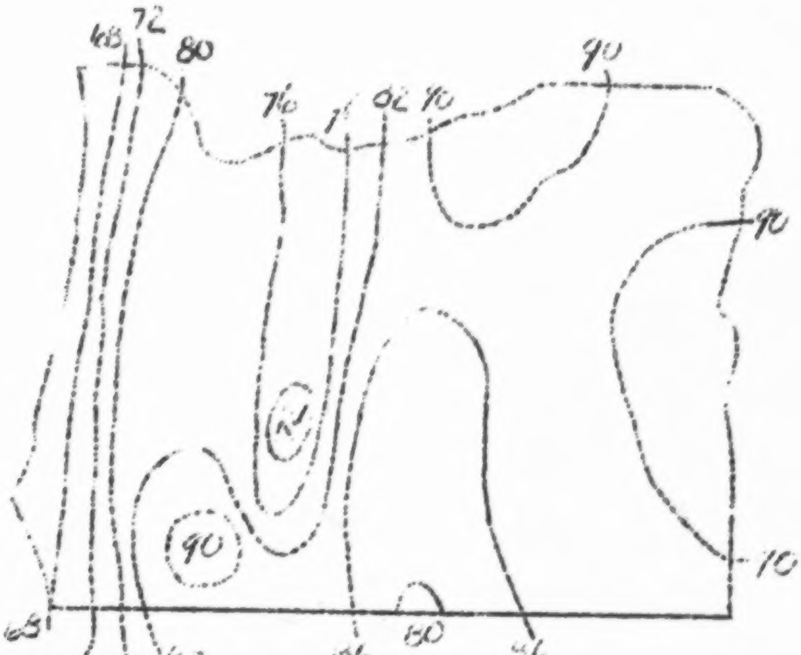
36
48
46
46
48

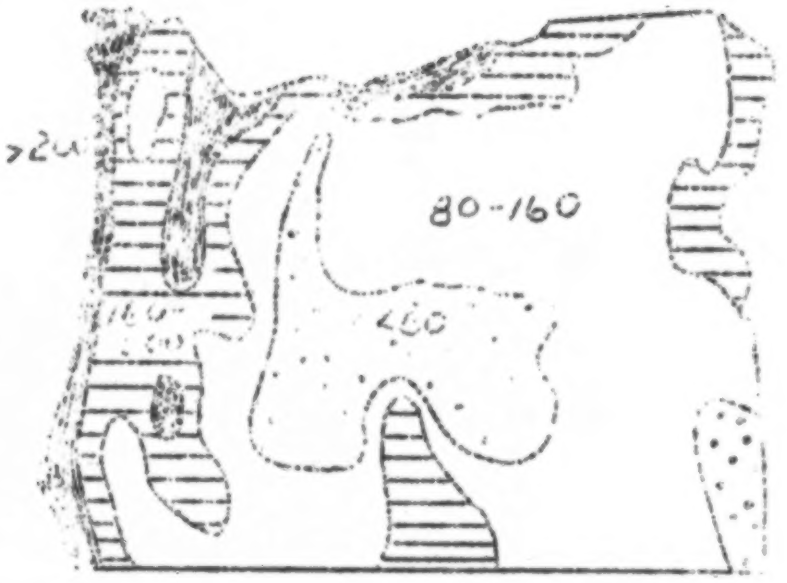
July

C - Average Low Temperatures (°F)

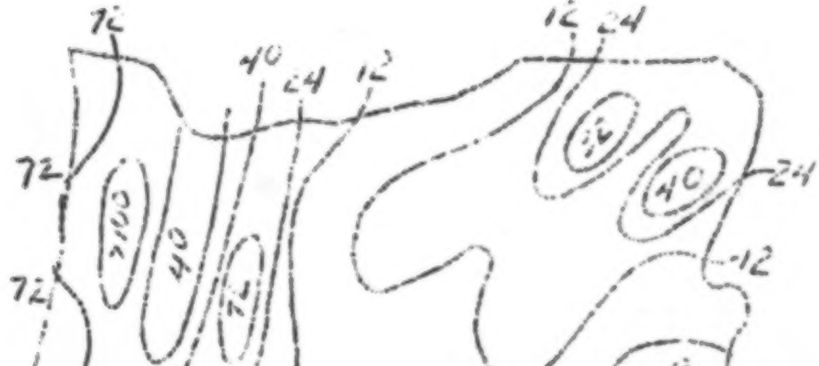

68
72
80
76
82
90
90
90
90
70
68
72
80
82
86
80
96

July

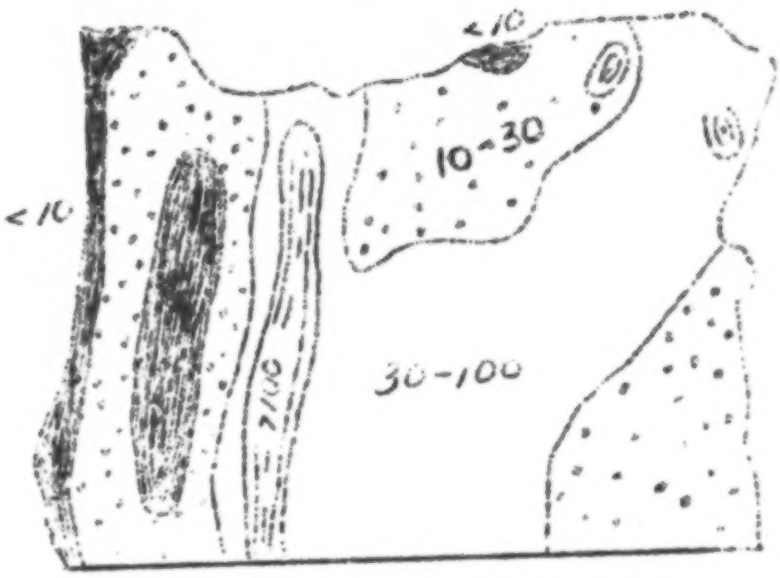
D - Average High Temperatures (°F)


>24
80-160
160-
<80

E - Number of Days from Last Frost of Winter to First Frost


72
40
24
12
12
24
72
72
100
40
72
24
40
24
-12
8
10
72
40
24
12

F - Annual Average Precipitation (inches)



G - Average Inches of Snowfall/Year

To answer these questions, use the maps in the pamphlets about Oregon organisms:

Do the distributions of the plants and animals correspond to the climatic regions or to specific features of weather? Cite specific examples.

If there is no obvious relationship between distribution and climate for some species, what is the controlling factor?

## XX.3 - A STUDY OF A COMMUNITY

Read pages 663-667, Blue text.

### XX.3a - Experiment: FIELD STUDY PROJECTS

You will be given time to conduct a field project of your own in which you will apply the information and techniques learned during this course. You will be expected to make a written report to explain your project. This report should include what you are attempting to accomplish; the equipment you used; the procedure or techniques you used during the project; the data you have collected; and, most important, an explanation or conclusion drawn from your data.

Below are listed some possible field projects. Your teacher will explain each and what is expected in each. You may think of other projects, but check with your teacher for approval first.

(a) Lab 3.1 Green--Study of a Biotic Community

(b) Lab 9.1 Green--Field and Laboratory Study of a Pond Community

(c) Lab 9.4 Green--Exploring Marine Communities

(d) Lab 5.2 Green--Diversity among Angiosperms (expand to include a plant survey collection of your area)

(e) Lab 4.3 Green--A Dichotomous Key for Identification of Insects (expand to include an insect collection of your area)

(f) A Succession Study in Logged or Pond Areas

(g) A Willamette River Pollution Study

(h) A Field Population Study (small mammal, reptile, insect, etc.)

(i) A Study of an Insect Habitat and Life Cycle

(j) A Survey and Study of a Micro-Habitat

# - Appendix -

## Suggestions for Laboratory Procedures

A laboratory is a place where scientists look at phenomena under controlled conditions. It is a place for serious work. Always prepare for an experiment by reading the directions in the manual before you come to the lab. Make a special effort to know all precautions.

Do only the experiments approved by your teacher. If you wish to do an extension (this is encouraged), check with your teacher. This general rule is for the safety of you and your fellow students. Laboratory safety is as much an attitude as a set of rules. The lab will become a safe place for investigation if the student continually uses common sense about his safety and the safety of others. If any accident does occur, report to your teacher. What seems a minor injury may have severe consequences.

You will be asked to write laboratory reports. Opinions concerning the content of these reports vary greatly. It follows that teacher judgment will determine the type of laboratory reports you are asked to write. The following ways to improve laboratory reports are to be taken as suggestions only.

(1) Mistakes should not be erased. If there is room for the correction, the mistake should be crossed out without obliterating it and the correction made. If there is insufficient room, an extra piece of paper should be added.

(2) Spelling and punctuation are important. Sentence fragments should be avoided.

(3) The report should be carefully planned. It is best to know what type of observations should be sensed and, if possible, what regularities can be found. Planning will lead to the placement of items in a logical sequence in the report.

(4) The name of the experiment should be included.

(5) The date on which the experiment was done should be included.

(6) The names of all participants should be included and the name of the person who actually prepared the report should be designated.

(7) Some reports should include a simple statement or schematic diagram of the apparatus used in the investigation.

(8) Some reports will require a brief explanation of purpose and procedure. If these are given in the laboratory manual, they should not be included in the report. Copying items is "busy work."

(9) Nearly all experiments require taking measurements and subsequent collection of data. This must be carefully tabulated. If it is possible for you to make data tables before coming to the laboratory, you will have more time for observation, which is a major part of any laboratory experience.

(10) If computations are required to interpret results, they should be included in the report. However, if several computations of a similar nature are needed, they should be illustrated with a typical example. Mathematical equations, not arithmetical operations, should be shown.

(11) If the investigation could be altered to get better results, a statement to this effect should be included.

(12) If the investigation suggests extensions, these should be described.

(13) Reading professional reports from magazines such as The Journal of Chemical Education and Scientific American should result in better reports.

(14) Many times the most significant information about the experiment is to be found by graphing results. Whenever appropriate, graphs should be included in the report; they give a picture from which regularities can be sought. You will find the following suggestions very helpful.

(a) Always use a full sheet of graph paper.

(b) Position the ordinate and abscissa far enough from the edge of the paper to allow proper labeling.

(c) Assuming a relationship exists, the abscissa should represent the independent variable; the ordinate, the dependent variable. As an example: The distance of the gas pedal from the floorboard in an automobile would be the independent variable, plotted on the x axis; while the speed of the car would be the dependent variable, plotted on the y axis.

(d) Each axis must show units--e.g., cm/sec.

(e) Labeling of each axis should run parallel to the axis.

(f) The scale of each axis should be chosen such that the functional plot covers most of the graph paper.

(g) The name of the graph, the name of the experiment and the date of the experiment should be suitably placed on the graph.

(h) When plotting data, draw a circle around each point to indicate the uncertainty associated with the measurements.

(i) Draw the smoothest possible curve suggested by your data.